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ABSTRACT

This report is concerned with the relationship between income and schooling. A theoretical model explores the role of schooling as an informational or screening device with an expected profit maximization framework. The issue revolves around the extent to which formal schooling serves to augment worker productivity and, thus, social product, as opposed to conveying information to employers about the probable productive capabilities of prospective workers without, in itself, affecting those capabilities. Empirical tests are formulated to disentangle schooling's productivity augmenting and identification functions. The conclusion drawn is that the apparent use of schooling as a screening device does not appear to stem from a mere identification of productivity types. In fact, the pure productivity augmenting view of the income-schooling relationship appears greatly more tenable. (Author/KSM)

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EDUCATION, SCREENING AND THE DEMAND FOR LABOR OF UNCERTAIN QUALITY

by

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16. Abstract

This report was concerned with the relationship between income and schooling. A theoretical model was developed which explored the role of schooling as an informational or screening device within an expected profit maximization framework. Several propositions concerning the demand for factors of production of uncertain quality demonstrated.

Empirical tests were formulated to disentangle schooling's productivity augmenting and identification or screening functions. The evidence suggested the former to be the more tenable view.

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SUMMARY

Since the advent of the human capital concept, much research has been devoted to the relationship between income and schooling. Previous studies have clearly demonstrated that schooling exerts a substantial positive effect on earnings even after attempting to control for innate ability and family background characteristics. Recently, questions have been raised concerning the underlying nature of the observed relationship between income and schooling, in essence, the link upon which it rests. The issue revolves around the extent to which formal schooling serves to augment worker productivity and, thus, social product, as opposed to conveying information to employers about the probable productive capabilities of prospective workers without, in itself, affecting those capabilities.

The study first explored a theoretical model of this latter "screening" role and then attempted an empirical investigation of its relative importance. The basis for the model was that individual productivities are unknown to the firm prior to hiring and neither instantaneously nor costlessly determinable from direct observation of on-the-job performance. The information available to the firm was restricted to knowledge (a subjective notion was also treated) of the first two moments of the population's skill distribution with output

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a function of occupation-specific aggregate skill levels and capital. Within an expected profit maximization framework, uncertainty or risk in the form of skill variance was shown to lead to a reduction in expected profits at the previous input scales and to substitution and production effects on factor employment. It was further demonstrated that the demand for workers associated with a given schooling group depended upon both the average skill level and the variance-mean skill ratio of the group. Thus, schooling's private return could be viewed as a reflection of its informational content, i.e., its sorting function. Further, eliminating between group skill variance through the use of identification or screening devices was shown to lead to a more efficient allocation of workers both within and across firms. Therefore, even if the higher average skill levels associated with the more schooled were not produced in the schooling process, schooling's social benefit would not be zero.

Although several tests aimed at distinguishing between the two views were conducted, probably the strongest test for the existence of an identification effect was based upon a comparison between schooling's return to self-employed and private wage and salary workers. Since the former are not subject to a screening process, i.e., there is no need for them to identify their capabilities through formal schooling, the absence of a productivity effect should be manifested in a lower return to schooling than for the latter group. Using the NBER-Thorndike sample discussed more fully in the text, earnings regressions were estimated and profiles of the two worker classes compared. The schooling effect, in general, was not "significantly" different for the two groups. Similar results were obtained for a comparison of the effect of higher

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"quality" undergraduate training in earnings between the two classes; earnings of the self-employed were seen to be equally augmented by greater quality schooling.

The conclusion drawn from this and other independent evidence was that the apparent use of schooling as a screening device did not appear to stem from a mere identification of productivity types. In fact, the pure productivity augmenting view of the income-schooling relationship appeared greatly more tenable.

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CHAPTER I

INTRODUCTION

Since the formulation of the human capital concept, much attention has been focused on the relationship between income and schooling. That schooling exerts a substantial positive effect on income has been well documented. Direct calculations of internal rates of return to schooling performed in the earlier studies of Becker (3), Hansen (10), and others clearly demonstrated that, as an investment, schooling was competitive with physical investments. Later research, attempting to control for innate ability and family background characteristics which could impart upward biases to the estimate of schooling's return, in general, did not diminish this finding.[1]

However, a more fundamental question has recently been raised involving the underlying nature of the observed relationship between income and schooling, in essense, the link upon which it rests. The issue revolves around the extent to which formal schooling serves to augment worker productivity and, thus, social output, as opposed to conveying information to employers about the probable productive capabilities of prospective workers without, in itself, enhancing those capabilities. In other words, the investment in schooling may serve the purpose of enhancing one's skills (the human capital view) and/or of identifying oneself as a more productive person (the screening view).

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[1] See Grilliches and Mason (9), Hause (11), or Gintis (7).

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Although the private rate of return to schooling may be invariant to the mix between the "productivity" and "identification" effects, the social return depends crucially upon their relative importance. In the extreme, if schooling's sole function is informational, its social product is related exclusively to the social value of the information imparted.

A brief outline of the dissertation will serve to demonstrate its aims. In Chapter II a model is developed which explores the impact of labor quality uncertainty on a competitive firm's demand for productive factors. Given imperfect information about worker productivities, a rationale is shown for the use of screening devices which segment the population into classes differing with respect to their "skill" distribution parameters. In particular, firms are shown to pay a premium to workers associated with (schooling) groups with higher mean skill levels and lower variance-mean skill ratios, the latter component being a return based upon the relative riskiness of the input.

The model is, however, only a partial analysis as schooling decisions are ignored. In Chapter III several models incorporating this aspect are critically surveyed. The proposition is that individuals, in maximizing incomes, may choose schooling levels in a manner systematically related to their endowed market productivities which, being based upon what firms believe the schooling-productivity relationship to be, exactly conforms to those beliefs. The crucial assumption is that schooling acquisition costs are negatively related to market capabilities. A modification of this assumption is explored in the text. Moreover, as a direct consequence of the presumed production process, aggregate output is unaffected by the placement of workers

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either within or between firms. Using the model presented in Chapter II, several possible sources of aggregate output gains associated with the efficiency of the screening process are isolated. The latter part of the chapter surveys two empirical studies. The first attempts to show the existence of a productivity effect while the aim of the second is to demonstrate a screening effect, although a somewhat different one than that described above.

In Chapter IV the results of further empirical tests are reported. An attempt is made to isolate both the mean and variance components of schooling's return mentioned above.

Chapter V presents a summary of the major theoretical and empirical findings of the dissertation.

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CHAPTER II

THE DEMAND FOR FACTORS OF PRODUCTION UNDER IMPERFECT INFORMATION WITH APPLICATIONS TO EMPLOYMENT SCREENING

In this chapter the behavior of a competitive firm whose labor inputs are of uncertain quality is analyzed. The problem arises for the firm because it must choose its workers from a population composed of individuals possessing a diverse set of productive attributes or skills, most, or even all, of which are not directly observable by the firm prior to an individual's employment. Productive attributes are defined so as to include both concrete technical skills and personal characteristics such as motivation and responsibility. In short, the set consists of all attributes perceived by the firm as contributing to an individual's productivity. However, since education can be viewed as either augmenting some of the elements in an individual's vector of productive attributes or as a predictor of these elements, or both, it is not considered as belonging to the set. Similarly, race, sex, experience, marital status, family background, and other characteristics which (may) serve as possible information sources to the firm are excluded. By using this classification scheme we wish to draw a sharp distinction between those items which enter directly into the firm's production function and those which may simply segment the population into subgroups whose skill vector distributions may possibly differ. To clarify this distinction we will refer to the former as elements of an individual's human capital stock and to the latter as "screening devices." Note that a screening device is not necessarily a passive instrument, but, as in the case of experience, may possibly augment an individual's stock of marketable skills.

To be more concrete, let $k_i = (k_{i1}\ k_{i2} \ldots\ k_{in})$ be the i^{th} individual's vector of productive attributes, where the total skill set

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consists of n different types; thus, for any single individual some of the elements may be zero. Corresponding to each occupation there is assumed to exist a function which transforms these elementary productive attributes into a skill index. The i^{th} individual's skill index for the j^{th} occupation is given by $s_{ij} = f_j(k_{i1}, k_{i2}, .., k_{in})$. Since individuals vary with respect to their human capital vectors, it is possible for individuals to have different skill indexes across occupations and within occupations to have some dispersion in skill indexes across individuals.

The production process within the firm is assumed to take the following form:

$$(1) \quad Y = F(S_1, S_2, ..; S_v, K)^1$$

where $S_j = \sum_{i=1}^{L_j} s_{ij} = f_j(k_1) + f_j(k_2) + ... + f_j(k_{L_j})$;

S_j = aggregate skill for the j^{th} occupation,

L_j = the number of workers employed in the j^{th} occupation,

and K = non-labor inputs.

The firm, therefore, is envisioned as employing individuals for particular occupations or job categories.

With perfect certainty as to each individual's human capital vector the i^{th} person's market wage for the j^{th} occupation is given by $r_{s_j} s_{ij}$, i.e., the product of the competitively determined real rental rate per

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1 Positive and diminishing marginal products are assumed.

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unit of the j^{th} skill index and the i^{th} individual's skill index for that occupation.[2] Hence, within the framework of fixed human capital vectors, both inter- and intra-occupational wage differentials can be generated.[3] Moreover, group wage differentials within occupations would exist solely as a result of differences in group averages. For example, the relative wage of high school to college graduates would, for the j^{th} occupation, equal $\frac{r_{sj}\,\bar{S}_{Hj}}{r_{sj}\,\bar{S}_{cj}} = \frac{\bar{S}_{Hj}}{\bar{S}_{cj}}$ where $\bar{S}$ denotes the average level of the skill index. However, group differences over the entire population also depend upon the allocation of workers to occupations. With perfect information this would be accomplished so as to ensure each worker, given his skill vector, receiving his maximum possible wage (utility adjusted).[4]

---

[2] The i^{th} individual's marginal product in the j^{th} occupation is

$$\frac{\partial F}{\partial L_i} = \frac{\partial F}{\partial S_j} \cdot \frac{\partial S_j}{\partial L_{ij}} = \frac{\partial F}{\partial S_j} \cdot s_{ij}$$

[3] It would be interesting to explore this certainty model in a general equilibrium context of occupational choice allowing for human capital augmentation. See Fn. 4, 5 for a further discussion of this point.

[4] Although occupational choice is not considered in the model that follows, one can easily see that the return to schooling, for example, is not invariant to this choice if productive attributes, and, therefore, skill indexes are differentially augmented.

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The increment in output from an additional unit of the ℓ^{th} elementary skill due to the employment of an extra worker will depend upon the function to which the worker is allocated. The marginal product of the ℓ^{th} skill when applied to the j^{th} occupation within the firm is

$$(2) \quad MP_{ij} = \frac{\partial F}{\partial S_j} \frac{\partial S_j}{\partial k_\ell} = \frac{\partial F}{\partial S_j} \frac{\partial f_j}{\partial k_\ell} = \frac{\partial F}{\partial S_j} f'_{j\ell}$$

i.e. its addition to the aggregate skill index times the marginal product of the skill index. For example, an extra unit of typing skill may have a high marginal product when embodied in an individual employed as a secretary but a negligible one when embodied in a manager for whom its skill index contribution is small.[5]

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[5] Notice that the factors being purchased in the market are the skill indexes and not the elementary attributes. Since the former are technologically determined from the latter, it is possible for individuals to have redundant amounts of specific elements as, for example, in the case where all the transformation functions are of a fixed-coefficient nature and not all proportions of the elementary attributes possessed by individuals are represented in the occupational structure.

An alternative is to enter aggregate amounts of each attribute separately into the production process as in Welch (19), i.e., $Y = F(k_1, k_2, .., k_n, K)$. An individual's wage rate then depends upon his human capital vector and real rental rates on the n elementary productive attributes.

The specification in the text was chosen because it lends itself more easily to the problem of quality uncertainty.

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For the competitive firm, the profit maximizing level of the j^{th} aggregate skill index is found by equating the real rental rate per unit of the j^{th} skill index to the value of the j^{th} skill index's marginal product. Denoting S^*_j as this optimum, workers will be added until their combined aggregate skill index is equal to S^*_j. Each worker is paid a wage proportional to his contribution to S^*_j. However, firms would be indifferent as to the exact number of workers it employed to obtain its aggregate skill requirement; a firm employing 100 workers would be as profitable as one using 10. But this argument assumes transactions costs to be either negligible or unrelated to the number of workers. If, for example, there existed a specific training cost necessarily expended on each person, firms would attempt to economize on their physical labor inputs. The indeterminacy of the physical labor requirement stems from the fact that numbers do not independently enter into the production function and, thus, do not affect marginal skill products for constant skill inputs.[6]

Now, suppose that employers have no a priori estimates of human capital vectors. Instead, let the j^{th} skill index be distributed over the population with mean μ_j and variance σ^2_j, both of which are known with certainty by the firm. Each firm is seen as drawing a random sample from the total population for each occupation with $\bar{s}_j$ being the obtained sample skill mean for the j^{th} occupation. The first two moments of the sample mean are μ_j (the population mean) and σ^2_j/L_j

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[6] One could, of course, separately enter physical units (warm bodies) into the production function.

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where L_j is the size of the sample drawn (the number of workers employed). The firm receives $S_j = \bar{s}_j L_j$ units of the j^{th} aggregate skill index which is itself distributed with mean $\bar{S}_j = \mu_j L_j$ and variance $\sigma^2{}_j L_j$.[7] Upon expanding equation (1) around thepoint $(\bar{S}_1, \bar{S}_2, \ldots \bar{S}_v, K)$ and taking a second order approximation, we obtain

$$(4) \quad Y = F(\bar{S}_1, \bar{S}_2, \ldots \bar{S}_v, K) + \sum_{j=1}^{v} (\bar{s}_j - \mu_j) L_j \frac{\partial F}{\partial S_j}$$

$$+ \tfrac{1}{2} \sum_{j=1}^{v} (\bar{s}_j - \mu_j)^2 L_j^2 \frac{\partial^2 F}{\partial S_j^2} + \sum_{\substack{j \\ j \neq k}} \sum_{k} (\bar{s}_j - \mu_j)(\bar{s}_k - \mu_k) L_j L_k \frac{\partial^2 F}{\partial S_j \partial S_k}$$

where all partial derivatives are evaluated at $(\bar{S}_1, \bar{S}_2, \ldots \bar{S}_v, K)$. Since $E(\bar{s}_j - \mu_j) = 0$ and $E(\bar{s}_j - \mu_j)^2 = \sigma^2{}_j / L_j$, and, assuming that sampling is independent over the v occupations, expected output is

$$(5) \quad \bar{Y} = F(\bar{S}_1, \bar{S}_2, \ldots, \bar{S}_v, K) + \tfrac{1}{2} \sum_{j=1}^{v} \sigma_j^2 L_j F_{\bar{S}_j \bar{S}_j}$$

$$= F(S_1, S_2, \ldots, \bar{S}_v, K) + \tfrac{1}{2} \sum_{j=1}^{v} R_j \bar{S}_j F_{\bar{S}_j \bar{S}_j}$$

$$= \phi(\bar{S}_1, \bar{S}_2, \ldots, \bar{S}_v, R_1, R_2, \ldots, R_v, K)$$

where $R_j = \sigma^2{}_j / \mu_j$ = the variance-mean ratio for the j^{th} occupation, and

$$F_{\bar{S}_j \bar{S}_j} = \frac{\partial^2 F}{\partial S_j{}^2} \text{ evaluated at } (\bar{S}_1, \bar{S}_2, \ldots, \bar{S}_v, K)$$

Thus, expected output is that level of output obtained with certainty if labor were homogeneous plus a variance correction.

---

[7] $E(S_j - \bar{S}_j)^2 = E(\bar{s}_j - \mu_j)^2 L_j^2 = \sigma_j^2 / L_j \cdot L_j^2 = \sigma^2{}_j L_j$

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The basic predictions of the model can be illustrated most easily with a single aggregate skill input. Equation (5) reduces to

$$(6)\quad \bar{Y} = F(\bar{S}, K) + \tfrac{1}{2} R\bar{S}F_{SS}$$

$$= \phi(\bar{S}, R, K)$$

where $\bar{S} = \mu_L$,

μ = the population mean skill index, and

$R = \sigma^2/\mu$.

The variance-mean ratio can be interpreted as a measure of risk or uncertainty attached to the labor input in the following sense. If individuals possessed identical skill vectors so that $\sigma^2 = 0$, the profit maximizing level of aggregate skill could be obtained without error. For example, denoting S* as the optimal skill input and μ as the number of skill units embodied in each individual, $L^* = S^*/\mu$ would be the optimal labor input. This case is exactly analogous to that under perfect information since μ is known although the labor input is now determinate without resorting to the existence of transactions costs. However, if human capital vectors differ, $\sigma^2 > 0$, the firm can never be assured of obtaining S* regardless of the number of workers it decides to sample. The question is whether the firm will alter its employment decision in response to the introduction of uncertainty, i.e., skill variance.

The first effect attributable to the introduction of risk is a reduction in expected output at the original equilibrium input levels. This can be demonstrated by differentiating equation (6) with respect to skill variance (mean constant). This yields

$$(7)\quad \frac{\partial \bar{Y}}{\partial \sigma^2} = \phi_R \frac{\partial R}{\partial \sigma^2} = \frac{1}{\mu} \phi_R.$$

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However,

(8) $\phi_R = \frac{1}{2} \bar{S} F_{\bar{S}\bar{S}}$ which must be negative under the concavity assumption. Firms, therefore, will be risk averse, always preferring to sample from a population characterized by lower variance.[8,9]

The equilibrium conditions for the profit maximizing competitive firm are:

(9) $\bar{Y} = \phi(S, R, K)$

(10) $P_L = \lambda \phi_L$

(11) $P_K = \lambda \phi_K$

(12) $\lambda = P_Y = MC$

where P_L is the wage rate, P_k the real rental per unit of capital, and P_y the product price.

Totally differentiating equations (9), (10), and (11) with respect to skill variance, allowing inputs to vary but maintaining a constant mean skill index and writing in matrix form, yields

$$\begin{pmatrix} 0 & \phi_L & \phi_K \\ \phi_L & \phi_{LL} & \phi_{KL} \\ \phi_K & \phi_{LK} & \phi_{KK} \end{pmatrix} \begin{pmatrix} \frac{d\lambda/\lambda}{d\sigma^2} \\ \frac{dL}{d\sigma^2} \\ \frac{dK}{d\sigma^2} \end{pmatrix} = \begin{pmatrix} \frac{d\bar{Y}}{d\sigma^2} - \phi_{\sigma^2} \\ -\phi_{L\sigma^2} \\ -\phi_{K\sigma^2} \end{pmatrix}$$

---

8 $\phi_R = \frac{\partial \phi}{\partial R}$ and is obtained from equation (6).

9 In other words if faced with as fair gamble of receiving $\bar{S} + \varepsilon$ or $\bar{S} - \varepsilon$ each with probability $\frac{1}{2}$ or of receiving $\bar{S}$ with certainty the firm would select the latter since $\phi(\bar{S}, R, K) < \phi(\bar{S}, K)$.

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Solving for the three unknowns yields

$$(13)\quad \frac{d\lambda/\lambda}{d\sigma^2} = \left[\left(\frac{d\bar{Y}}{d\sigma^2} - \phi_{\sigma^2}\right) \Delta_o - \phi_{L\sigma^2} \Delta_L - \phi_{K\sigma^2} \Delta_K \right] /\Delta$$

$$(14)\quad \frac{dL}{d\sigma^2} = \left[\left(\frac{d\bar{Y}}{d\sigma^2} - \phi_{\sigma^2}\right) \Delta_L - \phi_{L\sigma^2} \Delta_{LL} - \phi_{K\sigma^2} \Delta_{KL} \right] /\Delta$$

$$(15)\quad \frac{dK}{d\sigma^2} = \left[\left(\frac{d\bar{Y}}{d\sigma^2} - \phi_{\sigma^2}\right) \Delta_K - \phi_{L\sigma^2} \Delta_{LK} - \phi_{K\sigma^2} \Delta_{KK} \right] /\Delta$$

where Δ is the determinant of the left hand square matrix and the subscripted Δ's are the relevant cofactors. (Subscripted ϕ's are partial derivatives).

We have shown the first effect to be a reduction in expected output at the original input levels. The second effect entails a movement away from the previously optimal factor ratio at the new lower level of expected output. This pure substitution effect can be isolated by setting $\frac{d\bar{Y}}{d\sigma^2} - \phi_{\sigma^2}$ equal to zero in (14) and (15), i.e., $\phi_L \frac{dL}{d\sigma^2} + \phi_K \frac{dK}{d\sigma^2} = 0$. The percentage changes in the two inputs are

$$(14')\quad \frac{1}{L} \frac{dL}{d\sigma^2} = \sigma_{LK}\, \alpha_K \left(\frac{\phi_{L\sigma^2}}{\phi_L} - \frac{\phi_{K\sigma^2}}{\phi_K} \right)$$

$$(15')\quad \frac{1}{K} \frac{dK}{d\sigma^2} = -\sigma_{LK}\, \alpha_L \left(\frac{\phi_{L\sigma^2}}{\phi_L} - \frac{\phi_{K\sigma^2}}{\phi_K} \right)$$

where σ_{LK} is the elasticity of substitution of labor (evaluated at μ) and capital, α_L is labor's share in total cost and α_K is capital's share in total cost.[10] The percentage change in the labor-capital ratio

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[10] $\alpha_L = \frac{L\phi_L}{L\phi_L + K\phi_K}$; $\alpha_K = \frac{K\phi_K}{L\phi_L + K\phi_K}$

$0 < \sigma_{LK} < \infty$

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is therefore

$$(16)\quad \frac{1}{L}\frac{dL}{d\sigma^2} - \frac{1}{K}\frac{dK}{d\sigma^2} = \sigma_{LK}\left(\frac{\phi_{L\sigma^2}}{\phi_L} - \frac{\phi_{K\sigma^2}}{\phi_K}\right).$$

The direction of the pure substitution effect is seen to depend upon the relative effect of variance on the marginal expected products of the two inputs. Since

$$(17)\quad \phi_{L\sigma^2} = \tfrac{1}{2}\left(F_{\overline{SS}} + \overline{S}F_{\overline{SSS}}\right)$$

and

$$(18)\quad \phi_{K\sigma^2} = \tfrac{1}{2}\mu\ \overline{S}\ F_{\overline{SSK}},$$

upon expanding equation (16) we find that the substitution effect is related to third partial derivatives.

$$(19)\quad \frac{\phi_{L\sigma^2}}{\phi_L} - \frac{\phi_{K\sigma^2}}{\phi_K} \sim \left(F_K F_{\overline{SS}} + \overline{S} F_K F_{SSS} - \overline{S} F_S F_{SSK}\right).$$

The signs of $F_{\overline{SSS}}$ and $F_{\overline{SSK}}$ indicate the rate at which the marginal product of skill declines with increased usage of labor and capital, respectively. Hence, if $F_{\overline{SSK}} > 0$, an increase in the quantity of capital retards the rate of decline in labor's marginal product (and raises its own marginal expected product) while a negative value for $F_{\overline{SSK}}$ implies an acceleration in the rate of decline of labor's marginal product (and a reduction in its own marginal expected product). A similar interpretation can be given to $F_{\overline{SSS}}$.

Therefore, depending upon the form chosen for the production function, the substitution effect may be either to increase or decreasc the employment of the risky input. From equation (17) we see that if $\overline{S}F_{\overline{SSS}} > -F_{\overline{SS}}$, the marginal expected product of labor may actually be

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enhanced with the introduction of uncertainty. Stated differently, it is possible for an increase in the labor input to reduce the negative impact of variance on expected output if the rate of decline of labor's marginal product is sufficiently slow, i.e., if F_{SSS}^{---} is sufficiently positive. Rewriting equation (6) as

$$(6') \quad \bar{Y} = F(S, K) + \tfrac{1}{2} \frac{\sigma^2}{L} .L^2. F_{SS}^{--}$$

an increase in variance raises σ^2/L which, since $F_{SS}^{--} < 0$, reduces expected output. Although increasing L does lower effective variance (σ^2/L), it may also have a deleterious effect on $L^2 F_{SS}^{--}$ even if F_{SSS}^{---} is positive. It is the combination of these two effects which dictate the sign of $\phi_{L\sigma^2}$. Simply stated, the sign of the pure substitution effect is determined by the relative effect of the two inputs in reducing the impact of variance on expected output. Thus, although uncertainty originates with the labor input, it may, nevertheless, be more efficient at reducing the variance effect on output than the capital input.

For example, in a quadratic production function, all third derivatives vanish so that the sign of the pure substitution effect must be negative, i.e., less of the uncertain factor is utilized.

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However, for a Cobb-Douglas production function $\phi_{L\sigma^2} > 0$ and $\phi_{K\sigma^2} < 0$, implying a positive substitution effect.[11]

Figure 1 illustrates the case of a negative pure substitution effect where A corresponds to the position prior to the introduction of an uncertain factor and B corresponds to the new equilibrium established at the lower level of expected output, $\bar{Y}_1$, after uncertainty is introduced. There are, however, two further effects. First, there is a direct production effect corresponding to a northward movement along the new expansion path in order to restore output to its previous level, $\bar{Y}_0$. Second, there is an induced production effect in response to a change in marginal expected cost after regaining the original output level. In figure 1, the direct effect is shown as a movement from B to C and the induced effect from C to D.

11

$$Y = AS^{\alpha_1} K^{\alpha_2} \; ; \; \alpha_1 \, , \, \alpha_2 < 1$$

$$F_{SS} = A\alpha_1 (\alpha_1 - 1) \bar{S}^{\alpha_1 - 2} \quad K^{\alpha_2} < 0$$

$$F_{SSS} = A\alpha_1 (\alpha_1 - 1) (\alpha_1 - 2) \bar{S}^{\alpha_1 - 3} \quad K^{\alpha_2} > 0$$

$$F_{SSK} = A \alpha_1 \alpha_2 (\alpha_1 - 1) S^{\alpha_1 - 2} \quad K^{\alpha_2 - 1} < 0$$

$$\therefore \quad \phi_{I\sigma^2} = \frac{A}{2} \alpha_1 (\alpha_1 - 1)^2 \bar{S}^{\alpha_1 - 2} K^{\alpha_2} > 0$$

$$\phi_{K\sigma^2} = \frac{A}{2\mu} \alpha_1 \alpha_2 (\alpha_1 - 1) \bar{S}^{\alpha_1 - 1} K^{\alpha_2} < 0$$

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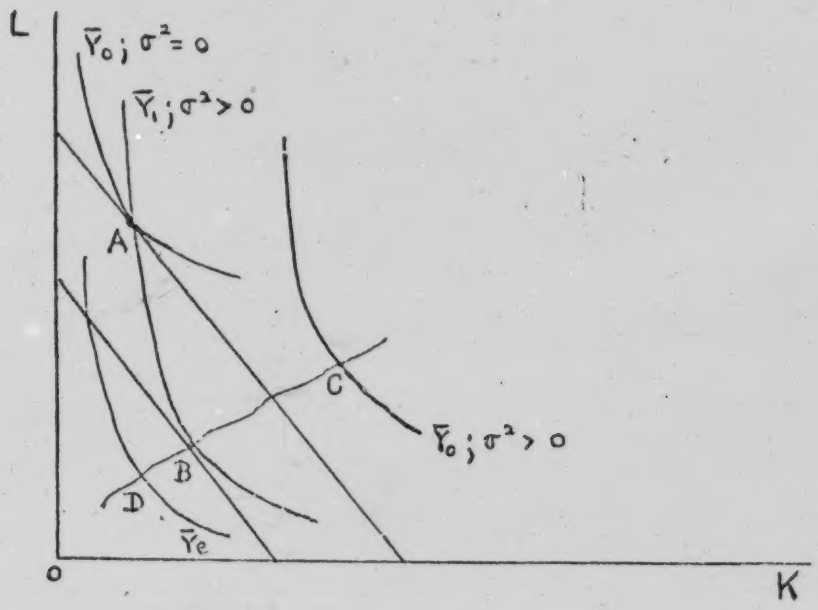
Figure 1. The Effect of Skill Variance on Factor Demand



Both the direct and induced effects are movements along the same expansion path and are in opposite directions. Marginal expected cost must increase with the introduction of uncertainty, i.e., MC must be larger at C than at A with $\sigma^2 = 0$. The new equilibrium level of output must, therefore, be lower than in the certainty case. The question is which of the two effects, the direct or the induced, will outweigh the other. The net scale effect is obtained by setting $\frac{d\bar{Y}}{d\sigma^2} - \phi_{\sigma 2} = 0$ in equation (13).

This yields

$$(13') \quad \frac{d\lambda/\lambda}{d\sigma^2} = -\left(\frac{\phi_{L\sigma^2}}{\phi_L}\,\frac{E\lambda}{EP_L} + \frac{\phi_{K\sigma^2}}{\phi_K}\,\frac{E\lambda}{EP_K}\right)$$

where $\frac{E\lambda}{EP_L}$ and $\frac{E\lambda}{EP_K}$ are the elasticities of marginal cost with respect to the factor prices of labor and capital respectively. The percentage change in marginal cost is a weighted sum of percentage changes in the

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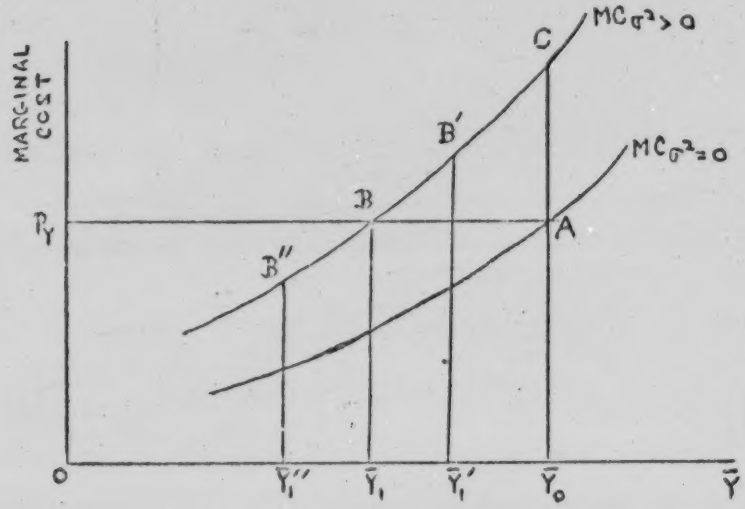
marginal products. If both factors are normal $\frac{E\lambda}{EP_L} \quad \frac{E\lambda}{EP_K} > 0$, the sign of the net scale effect depends solely on marginal expected factor product changes as in the case of the pure substitution effect. Figure 1 illustrates a positive net scale effect, i.e., a further reduction in the expected output from $\bar{Y}_1$ to $\bar{Y}_e$.[12]

---

12 For the competitive firm the scale effects are shown in the following figure. Labelled points correspond exactly to those in Figure 1. Given product price, P_y, output is at $\bar{Y}_o$ prior to the introduction of uncertainty. With the introduction of skill variance marginal expected



cost rises. There are three possibilities for the net scale effect. If the initial impact of uncertainty is to reduce expected output to $\bar{Y}_1$, the net scale effect is zero; the direct production effect is a movement from B to C and the induced effect from C back to B. If expected output initially falls only to $\bar{Y}_1'$ the direct production effect is outweighed by the induced effect and the net scale effect is positive; output falls further to $\bar{Y}_1$. Likewise B" illustrates a negative net scale effect.

For a monopolist, the substitution effects given by equation (16) are identical. The direction of the net scale effect, however, does not directly depend upon the sign of equation (13') but on the elasticity of marginal revenue with respect to output. For movements between B and C (those to the left of B must entail a larger output than that obtained after the initial output reduction), the net scale effect will be positive, zero, or negative, i.e., output will be lower, the same, or greater than the initial change as the magnitude of $\frac{d\lambda/\lambda}{d\sigma^2}$ given in equation (13') is larger, the same, or smaller than the percentage change in marginal revenue due to the initial output reduction.

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Extending the model to γ stochastic inputs (see equation (4)) yields the following equations for the pure substitution and net scale effects. (See Appendix A for derivation).

$$(20)\quad \frac{1}{L_i}\frac{dL_i}{d\sigma_j^2} = -\left[\sum_{k=1}^{\gamma}\frac{\phi_{L_k}\sigma^2_j}{\phi_{L_k}}\alpha_k\sigma_{ki} + \frac{\phi_K\sigma_j^2}{\phi_K}\alpha_K\sigma_{Ki}\right]$$

$$\frac{1}{K}\frac{dK}{d\sigma_j^2} = -\left[\sum_{k=1}^{\gamma}\frac{\phi_{L_k}\sigma^2_j}{\phi_{L_k}}\alpha_k\sigma_{kK} + \frac{\phi_K\sigma_j^2}{\phi_K}\alpha_K\sigma_{KK}\right]$$

$$(21)\quad \frac{d\lambda/\lambda}{d\sigma_j^2} = -\left[\sum_{k=1}^{\gamma}\frac{\phi_{L_k}\sigma^2_j}{\phi_{L_k}}\frac{E\lambda}{EP_{L_k}} + \frac{\phi_K\sigma^2_j}{\phi_K}\frac{E\lambda}{EP_K}\right]$$

where α_i = the i^{th} inputs share in total cost,

σ_{ij} = the Allen-Uzawa partial elasticity of substitution between the i^{th} and j^{th} inputs evaluated at their respective mean skill levels,

$$\phi_{L_k}\sigma^2_j = \tfrac{1}{2}\mu_k L_j F_{\bar{S}_j\bar{S}_j\bar{S}_k},$$

$$\phi_{L_j}\sigma^2_j = \tfrac{1}{2}\bar{S}_j F_{\bar{S}_j\bar{S}_j\bar{S}_j} + \tfrac{1}{2} F_{\bar{S}_j\bar{S}_j}$$

$$\phi_K\sigma^2_j = \tfrac{1}{2} L_j F_{\bar{S}_j\bar{S}_jK}$$

The pure substitution effect due to an increase in variance associated with the j^{th} labor input is, therefore, a weighted sum of percentage changes in marginal expected factor products, where the weights are products of factor cost shares and partial elasticities of substitution. If we can interpret third partial derivatives as third order substitution terms then equation (20) contains both second and third order substitution effects. In this interpretation a positive sign for $F_{\bar{S}_j\bar{S}_j\bar{S}_l}$ indicates that the i^{th} and j^{th} inputs are complementary while a negative sign implies competitiveness. The ℓ^{th} term in

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equation (19) will be negative if the introduction of variance either reduces the marginal expected product of the ℓ^{th} input and the ℓ^{th} input is substitute for the i^{th} input ($\sigma_{i\ell} > 0$) or the ℓ^{th} input's marginal expected product is enhanced and the ℓ^{th} input is complementary to the i^{th} ($\sigma_{i\ell} < 0$). (Note that a negative term results in increased usage of the ℓ^{th} factor). The marginal expected product of the ℓ^{th} input will decline if $F_{\bar{S}_j\bar{S}_j\bar{S}_\ell} < 0$, i,e., if the ℓ^{th} and j^{th} inputs are substitutes in the third order sense, and will rise if they are complements. A positive ℓ^{th} term (and thus a negative effect on L_i) will occur if either the ℓ^{th} input's marginal expected product is reduced and $\sigma_{i\ell} < 0$ or it is increased and $\sigma_{i\ell} > 0$. The net result will depend upon the cost shares attached to each factor.

For the quadratic production function, all third order substitution terms are zero; the pure substitution effect reduces to

$$(22) \quad \frac{1}{L_i}\frac{dL_i}{d\sigma_j^2} = -\frac{\phi L_j \sigma_j^2}{\phi L_j}\alpha_j\sigma_{ji}.$$

Since $\phi L_j\sigma_j^2 = \tfrac{1}{2} F_{\bar{S}_j\bar{S}_j}$ is negative, the sign of (22) is dictated by the sign of σ_{ji}. If the inputs are substitutes, $\sigma_{ji} > 0$, L_i will be reduced. Notice that since $\sigma_{jj} < 0$, the firm will always substitute away from the risky input (and its complements). Moreover, the net scale effect must be positive, i.e., the induced effect must outweigh the direct production effect. This will impart a further reduction in L_j's employment.

Consider a linear homogeneous production function. From Euler

$$\sum_{k=1}^{V} \bar{S}_k F_{\bar{S}_k} + KF_K = F(\bar{S}_1,..,\bar{S}_v,K).$$

Thus,

$$\sum_{k=1}^{V} \bar{S}_k F_{\bar{S}_k\bar{S}_j} + F_{K\bar{S}_j} = 0.$$

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Differentiating again with respect to $\bar{S}_j$ yields

$$\bar{S}_1 F_{\bar{S}_1\bar{S}_j\bar{S}_j} + \ldots + \bar{S}_k F_{\bar{S}_k\bar{S}_j\bar{S}_j} + \ldots + \bar{S}_j F_{\bar{S}_j\bar{S}_j\bar{S}_j} + F_{\bar{S}_j\bar{S}_j} + \ldots$$

$$+ \bar{S}_v F_{\bar{S}_v\bar{S}_j\bar{S}_j} + K F_{K\bar{S}_j\bar{S}_j} = 0.$$

But, $\quad \phi_{L_k}\sigma_j^2 = \tfrac{1}{2}\mu_k L_j F_{\bar{S}_k\bar{S}_j\bar{S}_j} \; ; \; k \neq j$

$$= \tfrac{1}{2}\bar{S}_j F_{\bar{S}_j\bar{S}_j\bar{S}_j} + \tfrac{1}{2} F_{\bar{S}_j\bar{S}_j} \; ; \; k = j$$

Therefore,

$$\sum_{k=1}^{v} L_k \phi_{L_k}\sigma_j^2 + K\phi_K\sigma_j^2 = 0$$

which implies that

$$\sum_{k=1}^{v} \alpha_k \frac{\phi_{L_k}\sigma_j^2}{\phi_{L_k}} + \alpha_K \frac{\phi_K\sigma_j^2}{\phi_K}$$

Hence for a linear homogeneous production function, the net scale effect is zero.[13] The substitution effect is, however, indeterminate.

Although the results of the previous analysis are somewhat ambiguous as to the effect of introducing a risky input on the employment of factors, the important point to note is that firms are definitionally risk averse; quality uncertainty, regardless of source, must lead to a reduction in expected output. The following extension makes use of this fact to show how the firm is able to reduce uncertainty through the use of screening devices.

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[13] For a linear homogeneous production function $\frac{E\lambda}{EP_{L_k}} = \alpha_k$.

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In the analysis that follows factors that influence the size of the screening return are identified. It is demonstrated that firms will pay a premium to those workers whose skill vectors are known with greater precision based upon group identification. In general, preference for workers within a given group will depend upon the group's mean skill index and its variance-mean ratio. Although the analysis is conducted with respect to education, other screening devices such as race or sex are equally applicable.

Suppose there are to be only two education classes denoted as E_H and where $E_C > E_H$. The corresponding parameters of the skill distributions associated with these classes are assumed to be (μ_C, υ_C^2) and (μ_H, σ^2_H). Awareness by the firm of this skill differentiating function of education would enable it to sample independently from within each schooling class. The firm's obtained aggregate skill would be $S = \bar{s}_H L_H + \bar{s}_C L_C$ with expectations $\bar{S} = \mu_C L_C + \mu_H L_H$ and variance $\sigma^2_H L_H + \sigma^2_C L_C$ where L_H and L_C are the number of individuals sampled from each group.[14]

The production function of equation (6) can now be written as

$$(23) \quad \bar{Y} = \phi(\mu_H L_H + \mu_C L_C, \frac{\sigma^2_H L_H + \sigma^2_C L_C}{\mu_H L_H + \mu_C L_C}, K)$$

where $\mu_H L_H + \mu_C L_C = \bar{S}$ and $\frac{\sigma^2_H L_H + \sigma^2_C L_C}{\mu_H L_H + \mu_C L_C} = R$. In the short run,

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14

$$E(S - \bar{S})^2 = E[(\bar{s}_H - \mu_H) L_H + (\bar{s}_C - \mu_C) L_C]^2$$

$$= \sigma^2_H L_H + \sigma^2_C L_C$$

under the assumption of sampling independence.

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with a fixed stock of capital, the marginal rate of substitution between L_H and L_C is given by

$$(24) \quad -\frac{dL_C}{dL_H} = \frac{\mu_H}{\mu_C}\left[\frac{\bar{S}\phi_{\bar{S}} - R\phi_R + R_H\phi_R}{\bar{S}\phi_{\bar{S}} - R\phi_R + R_C\phi_R}\right]$$

where $R_H = \sigma_H^2/\mu_C$ and $R_C = \sigma_C^2/\mu_C$.

First, suppose that individuals within schooling classes are homogeneous with respect to their skill indexes. Given that $\sigma_H^2 = \sigma_C^2 = 0$, education is an exact predictor of productivity, i.e., a "perfect" screening device. The employment of education as a screening device completely eradicates the uncertainty previously associated with the labor input. Since $R_H = R_C = 0$ equation (24) reduces to

$$(25) \quad \frac{-dL_C}{dL_H} = \frac{\mu_H}{\mu_C}$$

The marginal rate of substitution is, therefore, independent of the ratio of workers sampled from the two classes. Workers substitute perfectly for one another at the rate given by the ratio of their mean skill indexes, μ_H/μ_C. Diagramatically, isoquants relating L_C to L_H can be represented as straight lines with slope μ_H/μ_C. Figure 2 illustrates the case where $\mu_C > \mu_H$, i.e., where the more educated are also the more productive (a fewer number of them are needed to obtain a given level of expected output). Clearly, if the firm did not make use of this information it would not, other than under exceptional conditions, attain a profit maximizing position.

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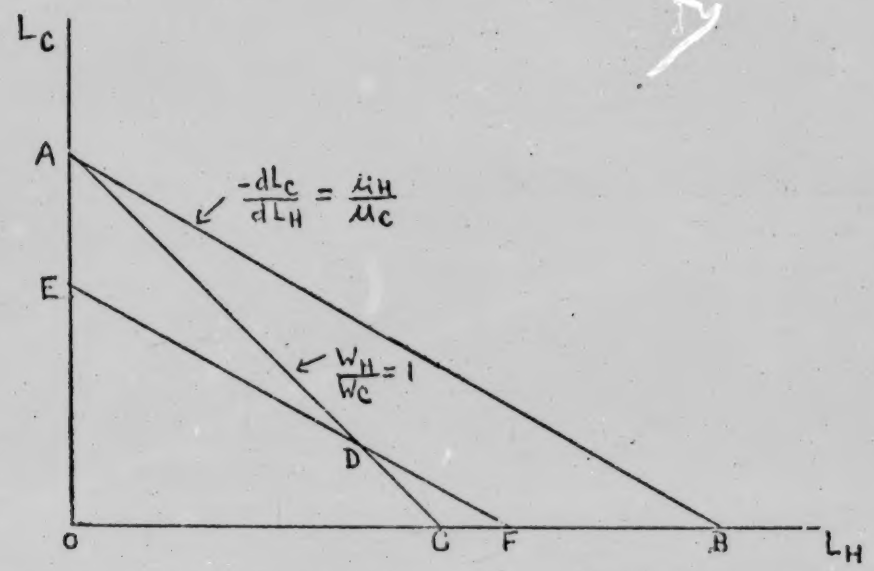
Figure 2. Factor Demand with Perfect Substitution Between Schooling Classes



With no screening, all individuals would be employed at identical wage rates regardless of educational attainment since the firm merely samples from the entire population (from which workers are indistinguishable). This situation is characterized by a total cost line (AC) having unit slope. In order for a firm to maximize its profits, its labor force would have to be composed solely of E_C workers. Assuming that educational attainment can be discerned at zero cost, the firm will always be in a better expected position when individuals are screened as long as the E_H set is non-empty. Any single firm can expect to earn excess profits from screening. To show this gain, let $\bar{L}$ be the optimal labor input determined from the initial analysis. Since AC has unit slope, it can be considered as the locus of points for which the total labor input is equal to $\bar{L}$, i.e., satisfying the constraint $L_H + L_C = \bar{L}$. Any point on this line represents the proportion of E_H to E_C workers obtained from sampling the entire population. Therefore, for the $L_C - L_H$ ratio given by D the gain due

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to screening (the loss from ignoring education's screening potential) is equal to the difference in revenue associated with the isoquants AB and EF, total cost being unchanged along AC.[15]

There are several reasons why education may fail to be a perfect screening device. First, if individuals differ in some nonproductive attributes, e.g., race, sex, family background, etc., which are somehow related to educational attainment but not themselves perfectly correlated with productivity, one would encounter some highly productive individuals in a low education class and vice-versa. Second, if there are more skill classes than there are schooling classes, at least one class must contain heterogeneous individuals. For either of these reasons non-zero variances are expected to occur.[16, 17]

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From equation (24) we see that when education is an imperfect screening device, workers from E_H and E_C are no longer perfect substitutes. A necessary condition for the isoquants to be convex is

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15 $\bar{L}$ will not usually be invariant to the use of the information. Scale effects are thus ignored, but the analysis is perfectly general for all input scales. The potential gain from screening is thus larger than determined above.

16 A third reason is, of course, that education is differentially productivity enhancing so that individuals are not equally affected by the schooling process.

17 See the more general discussion of this point in Chapter III and in Spence (16).

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that labor's marginal expected product be everywhere declining, i.e., $\phi_{\bar{S}\bar{S}} < 0$.[18] The marginal rate of substitution is strictly either greater than, equal to, or less than unity for all labor ratios. For example, with $\mu_H = \mu_C$ the MRS will be greater than one throughout if $R_C > R_H$ equal to one if $R_C = R_H$ and less than one if $R_C < R_H$. Thus, as in the perfect screening model, with equal wage rates, profit maximization would entail the employment of individuals from a single schooling class.

Preference for the more educated will be maintained only if

$$(26) \quad \sigma_H^2 - \sigma_C^2 > \left(\frac{\bar{S}\phi_{\bar{S}} - R\phi_R}{\phi_R} \right) (\mu_C - \mu_H).$$ [19]

Since $\phi_{\bar{S}} > 0$ and $\phi_R < 0$, individuals with more schooling will be preferred only if $(\sigma^2_C - \sigma^2_H)$ is less than some positive number times the difference in means $(\mu_C - \mu_H)$; it is not necessary for μ_C to be greater than μ_H and σ^2_C less than σ^2_H to obtain strict preference.

---

[18] The necessary and sufficient condition for convexity is

$$\phi_{\bar{S}\bar{S}} < \frac{\bar{S}\phi_{\bar{S}}}{\phi_R} F_{SSS}.$$

Therefore, the assumption that $F_{SSS} > 0$ underlies the statement in the text.

[19] E_C workers will be strictly preferred if and only if

$-\frac{dL_C}{dL_H} < 1$ which reduces to equation (26) above.

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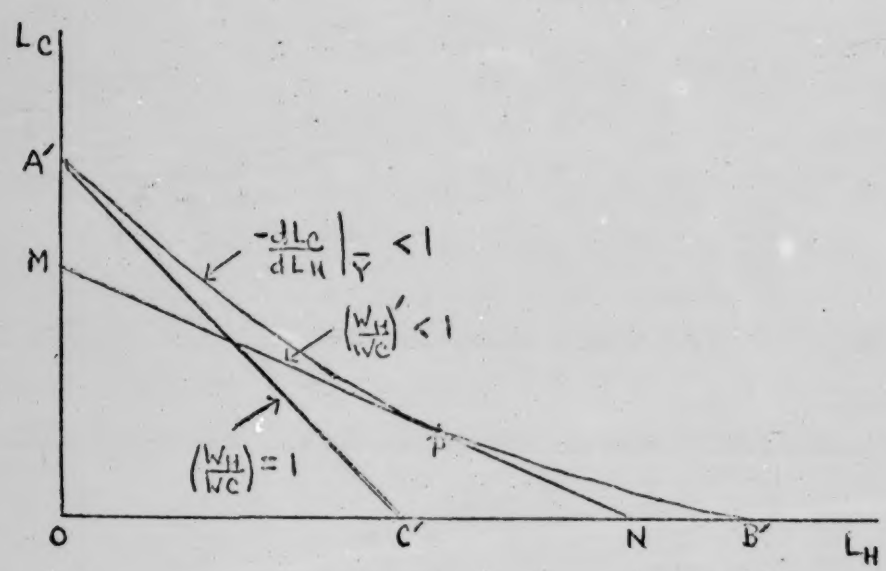
Figure 3 illustrates the firm's employment decision when inequality (25) is assumed to hold. Analogous to Figure 2, A'B' is a representative isoquant and A'C' is the isocost line (with unit slope). A corner solution is once again obtained (at A').

Figure 3. Factor Demand with Imperfect Substitution Between Schooling Classes



Clearly, the gain from utilizing the screen is a function of the degree to which skill parameters of the groups diverge. For any given labor input, $\bar{L}$, the return to employing an additional E_C worker (thus one fewer E_H worker) is given by

$$(27)\quad \frac{d\bar{Y}}{dL_C}\Big|_{\bar{L}} = \phi_{\bar{S}}(\mu_C - \mu_H) + \phi_R \frac{\mu_C \mu_H \bar{L}}{\bar{S}}(R_C - R_H).$$ [20]

---

[20] $$\frac{d\bar{Y}}{dL_C}\Big|_{\bar{L}} = \phi_{\bar{S}}(\mu_C + \mu_H \frac{dL_H}{dL_C}) + \phi_R\left(\frac{\partial R}{\partial L_C} + \frac{\partial R}{\partial L_H}\frac{\partial L_H}{\partial L_C}\right)$$

Substituting $\frac{dL_H}{dL_C} = -1$, $\frac{\partial R}{\partial L_C} = \frac{\mu_C \mu_H L_H}{\bar{S}^2}(R_C - R_H)$ and $\frac{\partial R}{\partial L_H} = \frac{\mu_C \mu_H L_C}{\bar{S}^2}(R_H - R_C)$ equation (27) is obtained.

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The marginal return to an extra worker belonging to the higher schooling class is, thus a positive function of $\mu_C-\mu_H$ and R_H-R_C.[21] Furthermore, assuming convexity, the revenue increment increases at a declining rate with further substitution toward the more favored group.[22]

Competitive bidding for the more educated will cause W_C to rise relative to W_H.[23] For example, in Figure 3, the new isocost line MN reflects the increased relative demand for E_C workers. As shown, a new equilibrium position is established at D where workers from both education classes are employed by the firm. Notice that when $R_C=R_H$ (L_C and L_H are perfect substitutes), an adjustment in relative wages to be equal to the ratio of mean skills will result in an indeterminate factor ratio. The firm would be indifferent as to the actual composition of its labor input once workers have been identified according to their educational attainment. In general, an explicit labor ratio will correspond to each set of relative wage rates.

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21 Note that the product $\mu_C\mu_H$ is being held constant.

22
$$\left.\frac{d^2\bar{Y}}{dL_C^2}\right|_{\bar{L}} = \phi_{\bar{S}\bar{S}}(\mu_C-\mu_H) + [\bar{S}^2\mu_C\mu_H\bar{L}(R_C-R_H)\phi_{R\bar{S}}(\mu_C-\mu_H)]/\bar{S}^4$$

$$-2\phi_R\mu_C\mu_H\bar{L}(R_C-R_H)(\mu_C-\mu_H)\bar{S}/\bar{S}^4$$

$$= \phi_{\bar{S}\bar{S}}(\mu_C-\mu_H) + \mu_C\mu_H\bar{L}(\mu_C-\mu_H)(R_C-R_H)[\bar{S}\phi_{\bar{S}R}-2\phi_R]/\bar{S}^3$$

But, $\bar{S}\phi_{R\bar{S}}-2\phi_R=\frac{1}{2}\bar{S}[\bar{S}F_{\bar{S}\bar{S}\bar{S}}-F_{\bar{S}\bar{S}}]$. Hence, with $\phi_{\bar{S}\bar{S}}<0, F_{\bar{S}\bar{S}}<0$, and $F_{\bar{S}\bar{S}\bar{S}}>0$ the result follows since $R_C<R_H$.

23 They may both rise if the introduction of uncertainty increases the overall demand for the labor inputs.

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Consider an extension of the model to two job categories within the firm as represented in equation (1) with $v = 2$. Suppose that individuals are homogeneous with respect to their skill indexes in one of the occupations, O_1, so that education serves no screening function with respect to it. At equal wages, firms would be indifferent as to education class to which an individual belongs when hiring for that occupation. On the other hand, suppose that the more educated are preferred for occupation two, O_2, on the basis of both skill distribution parameters. Since firms cannot distinguish among individuals within education classes, the wage paid to each type of worker must be the same for each occupation; for, if the wage paid to E_C workers was greater in O_2 than in O_1, the supply of E_C to O_2 would increase and that to O_1 decrease, thus destroying the initial wage advantage. As in the single occupation model, we can expect W_C/W_H to rise due to the increased aggregate demand for E_C workers. Figure 4 illustrates the effect of screening upon the employment decision within the two occupations. In O_2 an equilibrium is established at A where individuals from both education classes are hired while in O_1 the equilibrium occurs at B where only the less educated are employed.

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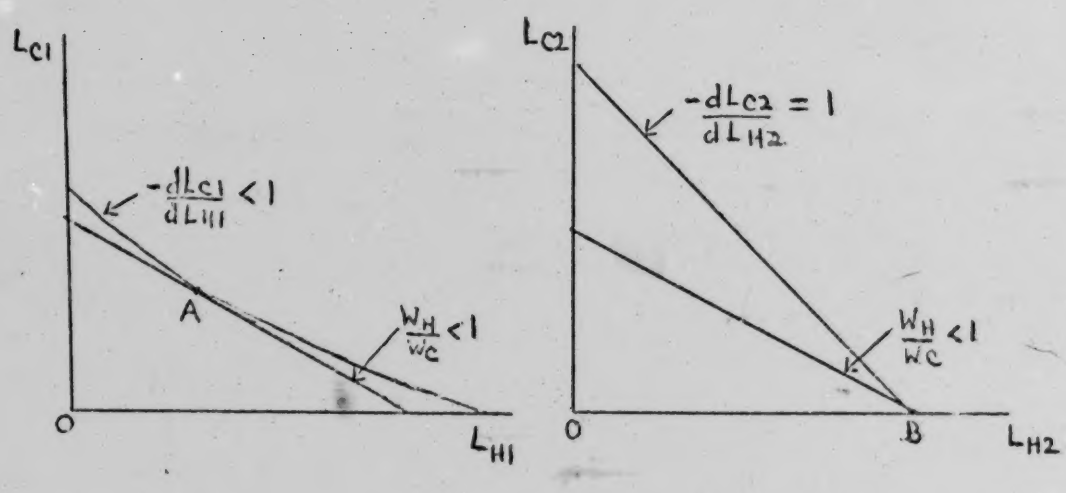
Figure 4. Two-Occupation Case: Perfect Substitution



As a second application, suppose that L_C workers are strictly preferred to L_H workers in both occupations but that the screening return is greater in O_1 than in O_2, i.e., $\frac{d\bar{Y}}{dL_{C_1}}\Big|_{\bar{L}_1} > \frac{d\bar{Y}}{dL_{C_2}}\Big|_{\bar{L}_2}$ due to larger differences in skill parameters in O_1 than in O_2. If, for example, $\sigma^2_{C_2} > \sigma^2_{C_1}$, all other parameters and technical considerations the same, isoquants corresponding to O_1 will be less steep than those of O_2. Thus, for any given set of relative wages, the proportion of L_C workers employed in O_1 will be greater than that in O_2. Stated

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24 Note that this could be due to technical considerations such as the impact of occupation-specific skill variance on expected output differing across occupations.

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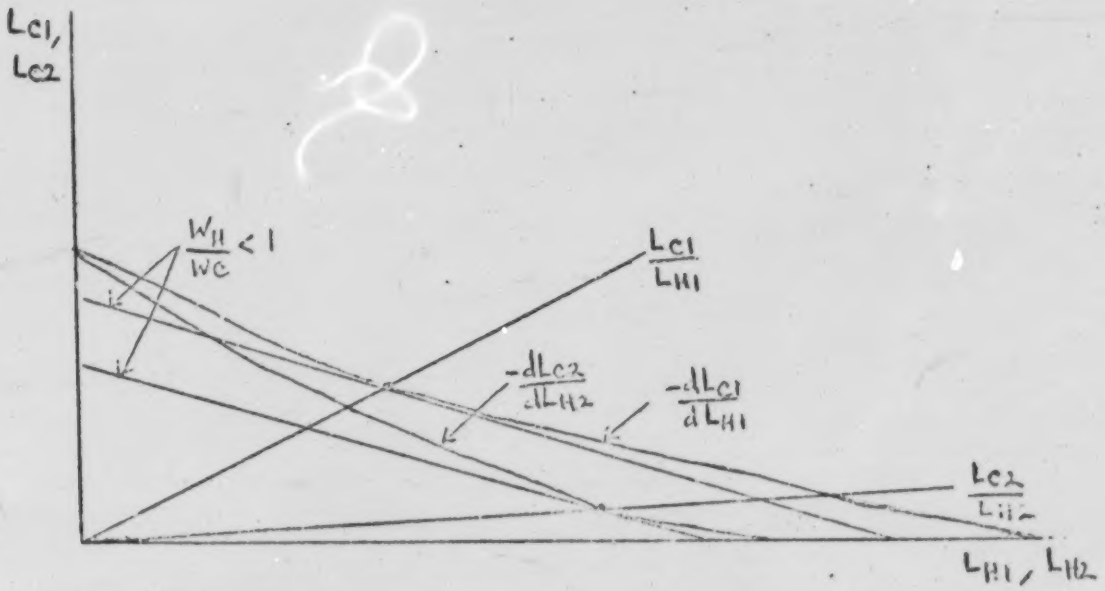
differently, L_C workers have an absolute advantage in both occupations but a comparative advantage in O_1 and, therefore, O_1 will be more L_C intensive than O_2. Figure 5 illustrates this situation.

Figure 5. Two-Occupation Case: Imperfect Substitution



Clearly, it will be advantageous for firms to utilize all zero cost screening devices as long as segmentation elicits inter-group skill parameter differences which lead to a positive screening return. From equation (27), we see that the size of the screening return is not only a function of the skill parameters but is also related to the marginal expected skill product (ϕ_S) as well as the impact of skill variance on expected output (ϕ_R). The extent of the return is not necessarily uniform over occupations, and, thus, education distributions may be widely divergent. Extensions to other negligible cost devices is obvious and leads to similar results. Thus, for certain occupations, individuals may be <u>required</u> to possess a specific set of characteristics,

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e.g., B.A. and 5 years experience, while for other occupations the set may be less restrictive, e.g., H.S. and no experience required. However, even within a narrowly defined vector of desireable characteristics substantial productivity differences may exist. If all zero or near zero cost screening devices have been exhausted, the firm faces the decision of employing any individual whose qualifications meet the desired specifications or of incurring some additional cost in attempting to more exactly predict individual productivity levels.

Suppose, for example, the firm administers a test to each prospective employee at a constant cost per candidate, h. The efficacy of such a device hinges upon its ability to predict an individual's skill index. For simplicity, assume that the device can segregate the population into two groups with skill parameters μ_t, σ^2_t and $\mu_{t'}, \sigma^2_{t'}$, where the t' group is preferred on the basis of these parameters. The test would act as a perfect screen if it divided the population into groups with zero variances; if no two individuals were exactly alike with regard to their occupational skill index, perfect predictability would require the discernment of each person's skill index.

Following our prior analysis, for any given number of workers, the marginal expected return from an additional preferred worker is given by

$$(28) \quad \frac{d\bar{Y}}{dL_{t'}} = \phi\bar{S}(\mu_{t'} - \mu_t) + \frac{\phi R\bar{L}}{\bar{S}^2}\mu_t\mu_{t'}(R_{t'} - R_t)$$

which, under suitable assumptions, has been shown to be a declining function of $L_{t'}$, the number of preferred workers employed. Let $p_{t'}$ be the proportion of $L_{t'}$ workers in the population, i.e., of those already screened on the basis of low cost devices $p_{t'}$ of them will perform well

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on the test and $1-p_t'$ poorly. It follows, then, that in order for the firm to obtain $\bar{L}$ preferred workers, it would have to sample, on average, a population of size $\bar{L}/p_{t'}$. The marginal expected cost of locating an additional preferred worker is given by $h/p_{t'}$ since the firm must sample $1/p_{t'}$ workers to find one more t' worker. Therefore, the larger the number of more productive individuals in the already restricted population, the smaller the cost of finding an additional t' worker because fewer will have to be sampled (on average).

Figure 6 depicts several equilibrium positions with respect to this type of screening device. The relevant portion of the marginal expected revenue curve is that lying to the right of the vertical line $\bar{L}p_{t'}\bar{L}p_{t'}'$ which represents the expected number of preferred workers obtained simply from sampling $\bar{L}$ workers. Three marginal expected cost curves are shown where $h_1 > h_2 > h_3$. At MEC_1 it will not pay the firm to administer the test; simply sampling $\bar{L}$ workers will have a higher expected net return. At MEC_3 the firm will test $\bar{L}/p_{t'}$ individuals, and, on average, the firm's total labor force will consist solely of the more skilled. An intermediate result is obtain for MEC_2 where $\hat{L}$ individuals are screened by their performance on the test and $\bar{L} - \hat{L}_{t'}$ workers (the rest of the firm's labor input) are obtained from sampling and no testing.

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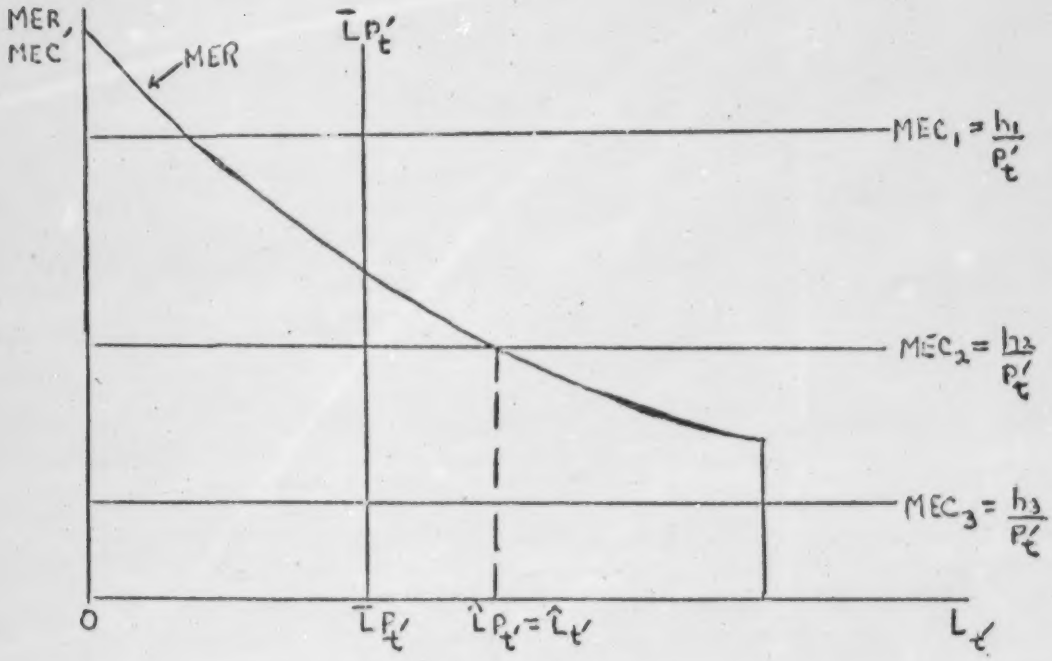
Figure 6 . Non-Zero Cost Screening Devices



One might expect that as the proportion of the more productive workers (p_t') increases, holding constant the group skill parameters elicited through testing, i.e., the more efficient are previous devices, the less likely is the firm to employ the test. However, as p_t' rises there are two effects. First, the MEC falls since the firm expects to obtain a given number of preferred workers with a smaller sample. Second, the expected number of preferred workers (obtained from sampling) increases for any fixed labor input, shifting $\bar{L}p_t$, $\bar{L}p_t'$ to the right. The net effect depends upon the elasticity of the MER curve with respect to L_t'. The more elastic it is, the more likely is the firm to use the

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test at higher levels of p_t'.[25] But the efficiency of previous screening devices also affect the usefulness of further testing. Clearly, it influences the skill parameters of the restricted population from which the firm would sample and, thus, the expected return from testing. In the extreme case, if schooling was itself a perfect screen, the potential efficiency of any costly screen would be irrevalent; the MER from utilizing the device would be zero as no further segmentation is possible. In general, each new device would have to sort more finely than the previous one in order for its MER to be positive. Notice that for education the MEC curve lies along the horizontal axis.

Thus, the factors which, in combination, influence the extent to which non-zero cost devices are utilized are their cost of development and administration, their ability to discriminate productivity types, the level of screening efficiency associated with previously applied zero cost devices, the effect of skill variance on expected output (the output cost of uncertainty, ϕ_R), and the marginal product of skill, ϕ_S. Since the importance of each probably varies across job categories (occupations as previously defined), one would expect to observe systematic occupation-specific differences in their overall screening intensities.

We have, so far, discussed only one type of uncertainty, namely, individual variation in productivity about some population average where both the mean and variance are known with certainty by the firm.

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[25] If, for example, p_t' doubles, MEC is halved and $\overline{Lp}_t$, Lp_t, is doubled. The proportion of individuals tested will increase, decrease, or remain the same as the elasticity of the MER curve is greater than, less than, or equal to unity.

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Moreover, distribution parameters have also been assumed known for all subgroups of the population. In this world, all firms are equally efficient at determining optimal input levels given intergroup skill differences, and, although the firm may learn about its individual workers, it gains no new information about group parameters. A model of adaptive learning would certainly be appropriate but is not within the purview of the current paper. Instead, a much simpler modification is pursued.

Assume that firms are, in actuality, unaware as to the true parameters of the skill distribution but maintain a subjective belief about them. Specifically, let $\hat{\sigma}^2$ denote the degree of uncertainty attached to the true mean of the population.[26, 27] Call this type II variance as opposed to σ^2, type I variance. Since firms may differ in their beliefs based upon prior experience (as long as σ^2 isn't zero firms will usually differ as to the skill parameters of the workers they actually employ), factor ratios may not be the same for all firms. One could define "managerial skills" to be the ability of entrepreneurs to estimate true parametric values, and, given some dispersion in this ability, one would expect firms to differ in their allocative efficiency.

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[26] μ subjectively distributed with mean μ and variance $\hat{\sigma}^2$.

[27] The case in which skill variance is also unknown is much more complicated and is not dealth with here.

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Expanding the model to include this type of uncertainty we obtain

$$(29)\quad \bar{Y} = F(\bar{S}_1, \bar{S}_2, \ldots, \bar{S}_v, K) + \tfrac{1}{2} \sum_{j=1}^{v} \sigma_j^2/\mu_j \, \bar{S}_j \, F_{\bar{S}_j\bar{S}_j} + \tfrac{1}{2} \sum_{j=1}^{v} \hat{\sigma}^2/\mu_j^2 \bar{S}_j^2 F_{\bar{S}_j\bar{S}_j}$$

$$= \phi(\bar{S}_1, \bar{S}_2, \ldots \bar{S}_v, R_1, R_2, \ldots R_v, \hat{R}_1, \hat{R}_2, \ldots, \hat{R}_v, K) \quad [28]$$

where $\hat{R}_j = \hat{\sigma}_j^2/\mu_j^2$ and the other terms are as previously defined. Notice that $\hat{\sigma}_j^2$ enters in a slightly different form than does σ_j^2. This is because uncertainty as to the value of μ_j is independent of sample size (at least prior to employment) while the variance of the sample mean is not. However, the introduction of type II uncertainty leads to similar results with respect to its impact on the firm's employment decision. For example,

$$(30)\quad \frac{\partial \bar{Y}}{\partial \sigma_j^2} = \frac{1}{\mu_j^2} \phi_{\hat{R}_j} = \tfrac{1}{2} L_j^2 \; F_{\bar{S}_j\bar{S}_j}$$

which, since $F_{\bar{S}_j\bar{S}_j} < 0$, is negative and, thus, the introduction of $\hat{\sigma}_j^2$ also leads to a reduction in expected output at the original input vector. Comparing equation (30) to equation (7-8) shows that the effect of a unit increase in $\hat{\sigma}_j^2$ is larger than that for a unit increase in σ_j^2. The reason is as follows: aggregate skill variance in the former case is a $\hat{\sigma}_j^2 \; L_j^2$ and $\sigma_j^2 \, L_j$ for the latter. Thus, for a given sample size, expected output will be more adversely affected by an increase in type II variance.

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[28] All covariances are assumed to be zero in the derivation. Thus sampling efficiency is unrelated to uncertainty as to the level of group means (see Appendix A).

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Now consider the one skill input production model. The pure substitution effects for changes in σ_j^2 and $\hat{\sigma}_j^2$ respectively are

$$(31a)\quad P_{\sigma^2} = \frac{1}{L}\frac{dL}{d\sigma^2} - \frac{1}{K}\frac{dK}{d\sigma^2} = \sigma_{LK}\left[\frac{\phi_{L\sigma^2}}{\phi_L} - \frac{\phi_{K\sigma^2}}{\phi_K}\right], \text{ and}$$

$$(31b)\quad P_{\hat{\sigma}^2} = \frac{1}{L}\frac{dL}{d\hat{\sigma}^2} - \frac{1}{K}\frac{dK}{d\hat{\sigma}^2} = \sigma_{LK}\left[\frac{\phi_{L\hat{\sigma}^2}}{\phi_L} - \frac{\phi_{K\hat{\sigma}^2}}{\phi_K}\right].$$

But, $\phi_{L\hat{\sigma}^2} = L[\phi_{L\sigma}{}^2 + \tfrac{1}{2} F_{\bar{S}\bar{S}}]$ and $\phi_{K\hat{\sigma}^2} = L\phi_{K\sigma^2}$, so that

$$(32)\quad \frac{P_{\sigma^2}}{P_{\hat{\sigma}^2}} = \frac{\phi_K\phi_{L\sigma^2} - \phi_L\phi_{K\sigma^2}}{L(\phi_K\phi_{L\sigma^2} - \phi_L\phi_{K\sigma^2}) + \tfrac{1}{2} LF_{\bar{S}\bar{S}}\phi_K}.$$

If $P_{\sigma^2} < 0$, then $P_{\hat{\sigma}^2}$ must be more negative. Thus, if the introduction of type I variance leads to substitution away from the risky input, the effect of type II variance will be reinforcing. However, if $P_{\sigma^2} > 0$, we cannot predict the sign of $P_{\hat{\sigma}^2}$; the labor input may be less efficient at reducing the effect of type I variance yet more efficient with respect to type II variance. Similarly, the ratio of the net scale effect is

$$(33)\quad \frac{N_{\sigma^2}}{N_{\hat{\sigma}^2}} = \frac{-(\phi_K\phi_{L\sigma}{}^2\frac{E\lambda}{EP_L} + \phi_L\phi_{K\sigma}{}^2\frac{E\lambda}{EP_K})}{-L(\phi_K\phi_{L\sigma^2}\frac{E\lambda}{EP_L} + \phi_L\phi_{K\sigma^2}\frac{E\lambda}{EP_K}) - \tfrac{1}{2} F_{\bar{S}\bar{S}}\phi_K\frac{E\lambda}{EP_L}}.$$

Thus, if $N_{\sigma^2} > 0$ so is $N_{\hat{\sigma}^2}$ while if $N_{\sigma^2} < 0$, no preduction about $N_{\hat{\sigma}^2}$ is possible. These results carry over exactly to the v input model.

To continue, suppose once again there to be only two education classes, E_H and E_C. Now, however, there are three parameters associated with each group's skill distribution (μ_H, σ_H^2, $\hat{\sigma}_H^2$) and (μ_C, σ_C^2, $\hat{\sigma}_C^2$) respectively. With v = 1 equation (29) becomes

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$$(34)\quad \bar{Y} = \phi\left(\mu_H L_H + \mu_C L_C,\ \frac{\sigma_H^2 L_H + \sigma_C^2 L_C}{\mu_H L_H + \mu_C L_C},\ \frac{\hat{\sigma}_H^2 L_H^2 + \hat{\sigma}_C^2 L_C^2}{(\mu_H L_H + \mu_C L_C)^2}\right)$$

assuming uncertainty as between groups to be un correlated.[29]

With K fixed,

$$(35)\quad -\frac{dL_C}{dL_H} = \frac{\mu_H}{\mu_C}\left[\frac{\bar{S}\phi_{\bar{S}} - R\phi_R - 2\hat{R}\hat{\phi}_R + R_H\phi_R + \frac{2\mu_H L_H}{\bar{S}}\hat{R}_H\hat{\phi}_R}{\bar{S}\phi_{\bar{S}} - R\phi_R - 2\hat{R}\hat{\phi}_R + R_C\phi_R + \frac{2\mu_C L_C}{\bar{S}}\hat{R}_C\hat{\phi}_R}\right].$$

which, analogous to equation (23), is the marginal rate of substitution between workers from the two education classes.

Following our previous logic, the marginal return to the replacement of a less-educated for a more-educated worker is given by

$$(36)\quad \left.\frac{d\bar{Y}}{dL_C}\right|_{\bar{L}} = (\mu_C - \mu_H)\phi_{\bar{S}} + \frac{\mu_C\mu_H\bar{L}}{\bar{S}}\left[\tfrac{1}{2}(R_C - R_H) + \mu_C L_C\hat{R}_C - \mu_H L_H\hat{R}_H\right]$$

At equal wages ($W_C = W_H$), there will be a positive screening return when $\left.\frac{d\bar{Y}}{dL_C}\right|_{\bar{L}} > 0$. With the inclusion of type II variance, we do not always obtain strict preference for E_C workers even given $\mu_C > \mu_H$, $R_C < R_H$ and $\hat{R}_C < \hat{R}_H$; the sign of equation (36) explicitly depends upon the L_C-L_H ratio. To illustrate, suppose that $\mu_C = \mu_H$, $\sigma_C^2 = \sigma_H^2$,

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29 This is probably the most severe of the covariance assumptions since one might expect, abstracting as we are from prior experiences, firms which are more uncertain about one group to be more uncertain about all groups.

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and $\hat{\sigma}_C^2 = \hat{\sigma}_H^2 \neq 0$. The screening return will still be positive for all values of L_C and L_H for which $L_C < L_H$, and, thus, in equilibrium firms will employ an identical number of workers from each group. However, no preference ordering is established, screening being pursued only to minimize the firm's aggregate level of uncertainty.

One can see that the impact of type II variance on factor intensities is not completely symmetric with that of type I variance. Type I aggregate variance ($\sigma^2 L$) is equal to $\sigma_C^2 L_C + \sigma_H^2 L_H$ while type II aggregate variance ($\hat{\sigma}^2 L^2$) is $\hat{\sigma}_C^2 L_C^2 + \hat{\sigma}_H^2 L_H^2$, so that, to take an extreme example, if $\sigma_C^2 = \sigma_H^2$, $\sigma^2 L = \sigma^2 (L_C + L_H)$, which for a fixed labor input is unaffected by its composition while if $\hat{\sigma}_C^2 = \hat{\sigma}_H^2 = \hat{\sigma}^2$, $\hat{\sigma}^2 L^2 = \hat{\sigma}^2 (L_C^2 + L_H^2)$ which is minimized only at $L_C = L_H$.

In general, the inclusion of $\hat{\sigma}^2$ does not change our previous results, serving only to mitigate or ameliorate the effect of σ^2 on the demand for the more educated. The extension to more than a single occupation also parallels the previous analysis. (See Appendix A).

In summary, there are three components of the private return to education. The first is attributable to differences in group mean skill levels which may or may not bear any other than an associative relationship to the educational process. From the point of view of the return itself, it is irrelevant as to the exact productive attributes enhanced by schooling, be they affective or cognitive, or even whether an individual's stock of human capital is actually altered by having passed through the educational system. As long as schooling groups differ as to their average level of productivity and information about individuals is imperfect, the demand for labor will be based upon group identification. The second component is a function of skill variances

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about the group means, the demand for labor of a given glass being negatively associated with its variance-mean ratio. The third part of the return is related to the firm's uncertainty as to the true value of group means; specifically, there is a negative relationship between the demand for a given group's labor services and the ratio of this type of variance to the square of the group's mean level of skill.

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CHAPTER III

A CRITICAL REVIEW OF THE SCHOOLING-SCREENING LITERATURE

The purpose of this chapter is to present a survey of some recent theoretical and empirical attempts to identify the underlying nature of the education-income relationship. The conventional view is that education enhances earnings via the production of marketable skills, the productivity augmenting view. But, the models presented in this chapter demonstrate that one need not assume greater productivity as the intermediary between schooling and earnings. Schooling's return may be informationally based. In the polar view education serves only to identify those individuals who are the more productive, the proposition being that an individual's productivity is unaffected by the schooling experience. This can be referred to as the "pure" screening hypothesis. Briefly, the notion upon which the screening view is based is that there exists some endowed productive characteristic or vector of characteristics which being unobservable to the firm and unaltered by formal schooling are nevertheless proxied for by educational attainment. One can think of these characteristics as endowed skills or ability. Ability, when used in this sense, specifically refers to those innate characteristics of an individual which produce earnings and should not simply be thought of as native intelligence. Through a mechanism to be outlined shortly, schooling and ability turn out to be positively correlated, and it is this association which leads to a positive return. That educational institutions produce something is not at issue. The question is rather to what extent their output serves

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to augment productive skills as opposed to being an informational device which segments the population into classes differing in their (average) ability endowments.[1]

One can, I believe, raise serious doubts as to the validity of the screening-only view both on intuitive and theoretical grounds. That there is a productivity effect appears from casual observation to be obvious. Professional schools clearly give job-specific training as do engineering and science-related undergraduate programs. Whether general liberal arts programs and non-vocational high school curricula do also is more problematic. The real question is with respect to schooling's dominant role, namely, the portion of its private return due to the direct acquisition of skills as opposed to factors which are, in a causal way, unrelated to educational success.

The models to be presented support almost any mix - one cannot form an opinion as to the relative importance of screening based on theoretical considerations. The major point of these models is that they present an alternative explanation of observed private rates of return to schooling which may have significantly different implications for social policy. For example, in the screening models surveyed in this chapter, the absence of a productivity effect would imply (ignoring income distributional questions) a negligible social investment in schooling as the appropriate policy. However, as demonstrated in a later

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[1] It has recently been argued by Gintis (7) that schooling's major role is as a socialization device and, thus, produces marketable traits. But, this possibility is also denied in the screening view.

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section of this chapter, the social return to schooling may also include an informational component. Although this role is not unrecognized in the literature, there are few formal statements concerning the nature of this function.[2] Empirical work in this area has been just as ineffectual in distinguishing the separate effects. This is not only due to the usual data limitations but more fundamentally to a problem of ingenuity in the development of appropriate tests. Many of the difficulties associated with testing the screening hypotheses are discussed in the empirical chapter.

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One can also reject the extreme screening view on theoretical grounds. For, suppose a firm were to hypothesize that education was serving only an identification function. If the firm could predict which individuals in the population would be successful in school, the firm could earn excess profits by attracting those individuals at a wage only slightly higher than their wage net of educational costs (their alternative wage after having identified themselves) yet less than their marginal products. I would think that the development of such a device would not be so costly as to inhibit its use. The fact that schools themselves use testing procedures for this purpose strengthens the argument. If such an information source were discovered, the usefulness of education as a screen would be destroyed, and, if this

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[2] Arrow does deal primarily with this aspect although in a different model than that presented below. Stiglitz (17) mentions several sources of a social return to identification but does not incorporate them into his work.

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were its only purpose, no investments in education would be undertaken. That this has not occurred appears to me to be a strong indictment of the extreme view.

One can more easily dismiss the naive screening view that firms merely believe there to be real productivity differences between individuals of different educational attainments when in fact none exist, i.e., all individuals are similarly endowed. In this case there would be no incentive, if actual productivities can be discerned from job performance, for firms to continue to reward newer cohorts of the more educated with higher wages. However, recent evidence suggests that private rates of return have been relatively stable or even possibly increasing over time.[3] Moreover, the existence of differential productivities is crucial to the more sophisticated screening models presented below.

Screening models are a subset of a much broader literature dealing with economic decision-making under uncertainty. The basis for this literature is the observation that many economic decisions are made with only imperfect information. Rothschild (14), in a recent survey of the literature on the existence of price variability in factor and commodity markets and the concomitant search procedures necessary to sustain such variations, persuasively argues that meaningful results can be obtained only by modelling the behavior of all market participants in a way which does not assume naive adjustments by one set of

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[3] See Welch (23) for a discussion of this point and also Grilliches (8) who contends that the future trend will show a decline in the rate of return.

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economic actors without recognizing the reactions of others to the information imparted by those actions. It will be useful to keep this remark in mind during the ensuing discussion.

As outlined in the previous chapter, the type of uncertainty associated with job market screening is with respect to labor quality. Firms must hire their workers from a population composed of individuals whose productive capabilities are unknown to the firm prior to the employment decision. The existence of transactions costs, specific training costs (the outcomes of which may depend upon initial ability), and time lags in the discernment of worker productivity from on-the-job performance monitoring will act as an incentive for firms to utilize devices which sort individuals according to their abilities. But, there is a more important reason for the use of screens. Any single firm can expect to gain a competitive advantage by identifying the more productive workers to the extent that the information gain is not appropriable by other firms. Any zero cost device (to the firm) will be employed as long as it discriminates, however imperfectly, between individuals. The argument is similar to the one previously made, namely, that if a competitive firm can costlessly determine who among the population are the more able, it will attempt to attract those individuals at a wage greater than their net alternative but less than their marginal product. If the information is public in the sense that if it is available to a single firm it is available to every firm, the more productive individuals rather than the firm will appropriate the gain. Firms will utilize any zero cost device, but individuals will (if the return is large enough) supply the information. See Stiglitz (17) for a fuller discussion of this point.

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To begin, consider the model developed in the previous chapter. In it, the effect of labor quality uncertainty on a competitive firm's employment decision is explored given the existence of a device (schooling) which sorts individuals into groups of known skill distributions. The production process is assumed to depend upon an aggregate skill input for each of several job tasks performed within the firm. The production function is assumed to exhibit positive and declining marginal products in all arguments. The firm is envisioned as drawing a random sample from the population (pre-screening) in order to obtain its optimal aggregate skill inputs, the decision variables being the number of workers to employ in each task and the quantity of a non-stochastic (riskless) capital input. Within an expected profit maximization framework, it is demonstrated that the firm pays a premium to those workers (with screening) whose schooling class has a higher mean skill level and a lower variance-mean ratio. The private return to screening is, therefore, directly related to the efficiency with which individuals are sorted into productivity classes, it being a function of mean skill differences and the relative homogeneity of the groups. Several further results emerge: (1) The private return to schooling does not depend upon a causal relationship between educational attainment and skill levels; (2) Even if mean skill differences were due to skill formation, the private return could be higher than that under perfect certainty if the sorting process created more homogeneous groups relative to their average at higher schooling levels;[4] (3) An individual's

[4] If there are more skill classes than schooling levels imperfections in the sorting process must exist. There is, however, nothing inherent in the sorting technology of the educational system which should lead to variance effects which favor the more schooled.

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wage depends less upon his own skill endowment than upon the skill levels of the individuals in the same schooling class. Ignoring variance effects, the less efficient the screen, i.e., the more low productivity types found in higher schooling classes and vice-versa, the lower the return to schooling; (4) Ignoring the distributional questions inherent in (3), schooling's gross social product is not necessarily zero even if its only function is as a screening device. As already noted, explicit presentations of this result are given in a later section.

The major objection to this model is that it ignores the reaction of individuals to the use of education as a screen. The question as to how the positive schooling-skill relationship emerges, given that there may be a negligible productivity effect, is left unanswered. In particular, since it is advantageous for any less productive individual to acquire the same image as the more productive, namely, more schooling, why is it that education can persist as a screen? Both Spence (16) and Stiglitz (17) approach the screening phenomenon from this perspective. That is, their models are couched in terms which take the employment decisions of the firm as given; firm size and factor intensities are not determined within the model. Analytically, their models are best viewed in the context of a single aggregate firm although competitive assumptions must be maintained. The firm is viewed as hiring all individuals in the population with a given skill distribution; there is no sampling problem. Marginal products are constant; aggregate output is simply the sum of the outputs produced by each individual and is unaffected by the existence of skill variance.

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Since the two models are qualitatively similar, to a large degree they will be merged in the discussion. Both authors do explore somewhat different questions after initially developing their models, but the main concern here is with their formal statements. Where the models are sufficiently distinct, the specific author will be cited.

Suppose there exists a uni-dimensional characteristic, β, which is strictly proportional to productivity. The characteristic will be referred to as ability. An individual possessing β_1 units of ability can produce in a given unit of time β_1/β_2 of what an individual of β_2 units of ability can produce. With an appropriate choice of scale, β can be considered equivalent to productivity. Ability is randomly endowed (at least from the firm's perspective) with given frequencies. The production process is such that the firm cannot determine, except at prohibitive cost, any single individual's ability. Each individual is assumed to know his own marginal product with certainty. Stiglitz envisions an assembly line process where the firm can monitor aggregate performance but not individual contributions to output; the speed of the assembly line is determined by the average value of β which for the single aggregate firm must be $\bar{\beta} = \int \beta f(\beta)\, d\beta$, where $f(\beta)$ is the frequency distribution of ability.[5] In the multi-firm case, $\bar{\beta}$ is the

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[5] Stiglitz notes that under alternative assumptions about the production process, as for example, in the case where low ability types reduce the speed of the line more than high ability types increase it, expected output will be a function of other ability parameters. In essence, this corresponds to the model developed in the previous chapter. It is not pursued by Stiglitz.

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expected speed of the line for any single firm so that with risk neutrality each worker is offered a wage of $\bar{\beta}$ if no prior information exists with respect to abilities. Since marginal products are constant, expected output is unaffected by the existence of ability dispersion.

Drawing on Stiglitz, suppose there exists a device which can potentially identify abilities perfectly but which must be purchased at a cost, C, which is independent of ability. Further, assume that once the label is bought the information is readily available to all firms so that no single firm will bear the cost of screening. For convenience, suppose there are only two types of workers with β_1 amd β_2 units of ability respectively where $\beta_1 > \beta_2$. Since the less productive individuals do not wish to be identified (as such) they will never purchase the screen at any positive cost since it will only certify to others something they already know and have a motive for keeping secret. If the more productive purchase the screen, their net income is $\beta_1 - C$. Now, a full screening equilibrium is possible as long as $\beta_1 - C > \beta_2$, i.e., net income after paying for the screen exceeds the level of income obtained by abstaining from its purchase (in which case they are taken to be β_2). A no screening equilibrium is also possible if $\beta_1 - C < \bar{\beta}$ since, if at any moment the device is not being used, each more productive person sees himself as having higher earnings if he remains indistinguishable. Thus, if

$$(1) \quad \beta_1 - \beta_2 > C > \beta_1 - \bar{\beta} ,$$

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at least two equilibria are possible.[6] Notice that if a full screening equilibrium occurs, every individual is worse off than if the information was unavailable even though each individual is rationally maximizing income given the prevailing information. If C is such that it does not satisfy the right-hand inequality, a full screening equilibrium must occur, and the more productive will be better off than without the screen. In either case, the full screening solution is socially undesirable as compared to no-screening since aggregate output is lower by the total output cost of the screen.

In this formulation, schooling can be an effective screen only to the extent that the educational system itself performs a sorting function since each individual faces the same identification cost. For a full screening equilibrium to exist, there must be no possibility for less productive persons to be confused with the more productive in the schooling-sorting process. The performance criteria employed for promotional purposes within the educational system must be perfectly

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6 As with most models of uncertainty, the question of dynamic adjustments is crucial but extremely difficult. Consider, for example, the no screening equilibrium. Given quality dispersion in a multi-firm setting, one would expect there to be output variation among firms. With the discernment of actual productivities impossible, wage rates would adjust under competitive conditions to the average ability of the individuals assigned to the line. The maintenance of a no screening equilibrium would be contingent upon no individual being able to improve his position by obtaining the label. But, individuals of equal ability now face different alternatives and, thus, have different incentives to invest in the screen. The stability of this equilibrium, is at least questionable and depends upon, among other things, the form of contractual obligations and the discernment of individual abilities.

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correlated with market productivity. In other words, educational institutions in the pursuit of their own goals (unless of course their major goal is job screening) impose a zero return or, what is operationally the same thing, an infinite purchase cost on the less productive. Those of type β_2 will never choose to enter the system because they have no possibility of obtaining the characteristic which could identify them as belonging to the class of β_1 types.

Notice that even if individuals misassess their true ability, a full screening equilibrium may be obtained. Suppose, for example, that some β_2 people believe that they really are endowed with β_1 units of ability. Those who have erred in their self-evaluation will simply bear the cost of finding out that they are really of low productivity. Since they are detected, full screening is preserved. Resources are, nevertheless, wasted in their acquisition of the label and the mistakes are socially costly. If, on the other hand, the more able underestimate their ability, a full screening equilibrium cannot be maintained as firms will find that the less educated have greater productivity than they anticipated. If in the extreme, as Stiglitz notes, individuals are very uncertain or sufficiently risk averse (in which case $\overline{\beta}$ is perceived as a better alternative than the outcome (β_1, β_2) with some given probabilities), the screen may be inoperative.

Clearly, education may fail to be a potentially perfect screen if schools make mistakes with respect to their evaluation of students and/or if the characteristics necessary to succeed in school are not exactly correlated with those which produce earnings. Suppose, for example, that schools function in such a way that the probability of success is independent of β (it need not be unity). This clearly leads

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to a no screening equilibrium since schooling actually conveys no information; all individuals, in effect, face the same purchase cost. On the other hand, if the probability of success is larger for β_1 types than for β_2 types, it is as if the two groups face different expected purchase costs. This is, in essence, Spence's basic assumption.

Spence posits that the two types can obtain the same schooling level (with perfect certainty) only if the less able expend more resources on education relative to the more able - in his terminology they face a higher signalling cost. If an individual pays his signalling cost, he is rewarded with a "good" image; if he does not, he has no chance of success. The assumptions of the previous model are, in general, maintained.

The firm, as before, does not know the true relationship between productivity and schooling but, based upon past employment experience, posits a set of subjective beliefs about the conditional distribution of productivity given schooling. Note that learning must take place in order for beliefs to be formed. As already noted, the performance criteria on which schools base their decisions are such that the less productive must expend greater effort (in the form of time or such things as tutoring) in order to be assured of gaining the same schooling level as the more productive can be assured of attaining with a smaller expenditure. As Stiglitz points out, if everyone could pass through the system without failure (or threat of failure), there would be no basis for differential signalling costs, the existence of which is necessary for education to be a viable screen. Only if performance barriers which conform to market productivities are established can effective screening occur.

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To illustrate the implications of this model consider the following configuration of subjective beliefs. The example is taken from Spence. All individuals with $\hat{E}$ years of schooling (or more) are believed to be of type β_1 and all those with less than $\hat{E}$ of type β_2, each with probability one. A signalling equilibrium is said to occur when the firm's prior beliefs are confirmed by its new market experience so that there is no incentive for the firm to alter its beliefs in the next round of hiring. Now, β_1 types will choose exactly $\hat{E}$ (they will never select more schooling than this since costs rise with no associated benefit) if and only if $\beta_1 - C_1(\hat{E}) > \beta_2$, where $C_1(\hat{E})$ is their signalling cost at $\hat{E}$ and $C_1(E)$ is a positive function of E. All β_2 persons select zero as their optimal level of schooling (if they select an amount less than $\hat{E}$, they will always select zero) if and only if $\beta_2 > \beta_1 - C_2(\hat{E})$ with $C_2(\hat{E})$ being their associated signalling cost. Given the prior assumption that signalling costs are negatively related to ability, $C_2(E) > C_1(E)$ for all E, a signalling equilibrium is established where

$$(2) \quad C_1(\hat{E}) < \beta_1 - \beta_2 < C_2(\hat{E}),$$

i.e., where the difference in productivities fall within the range of signalling costs evaluated at $\hat{E}$. A full screening equilibrium arises because, given the beliefs of firms, individuals self-select themselves into schooling classes which, due to sufficient differences in signalling costs, conform to those beliefs. By altering the initial priors, Spence demonstrates that other signalling patterns may emerge including one in which everyone obtains no schooling. This specific solution becomes relevant when other characteristics, particularly unalterable ones such as race or sex, are introduced. Although, these cases are

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interesting and possibly important, they are peripheral to this discussion.[7]

Consider the special case where $C_1(E) = 1/2E$ and $C_2(E) = 1E$. For simplicity let $\beta_1 = 2$ and $\beta_1 = 1$. The signalling equilibrium condition reduces to

$$(3) \quad 1 < \hat{E} < 2.$$

Notice that any arbitrary value of $\hat{E}$ within this range will lead to self-confirming beliefs. Increases in $\hat{E}$ serve only to reduce the earnings of the more educated.[8] Concomitantly, increases in $\hat{E}$ reduce social output; within the equilibrium range, lower levels of education are pareto superior to higher levels. Ignoring distributional aspects, the optimal social investment in education is zero.

Subsumed in this model is a specific relationship between private educational expenditures and success probabilities. Any expenditure less than the "full" signalling cost leads to failure, i.e., zero

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7 Spence does not explicitly exclude the possibility that the more able may avoid purchasing education and simply wait for firms to discover their true productivities. Since learning must occur in order to judge the validity of prior beliefs, such a strategy may in fact limit the efficacy of schooling's screening function. Some assumption about the learning process is necessary in order to fully specify the model.

8 Spence demonstrates that in the case of continuous subjective beliefs both groups may be worse off. All individuals would prefer a no screening solution.

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probability of success. But, suppose that individuals are free to choose lower signalling costs by taking reductions in success probabilities.[9] To accomodate this assumption, let the signalling cost functions be $C_1 = a(P)E$ and $C_2 = b(P)E$ where P denotes the probability of success and $a'(P), b'(P) > 0$. Signalling costs are assumed to be negatively correlated with productivity in the sense that the less productive must spend more in order to face the same probability of success, i.e., $a(P^*) < b(P^*)$ for all P^*. The notion here is that as individuals devote more resources to schooling, they begin to look more and more like they belong to the set of more efficient learners and, thus, even if schools performed solely a market screening function, the degree of error will be associated with individual expenditures.

To conform to the prior example, let $a(1) = 1/2$ and $b(1) = 1$. In order for the previous set of beliefs (see page 53) to elicit a signalling equilibrium each less productive person must choose not to enter the system at any positive p.[10] The condition for this is

$$(4) \quad 2P_2 + 1(1 - P_2) - b(P_2)\hat{E} < 1$$

$$\text{or} \quad \hat{E} > \frac{P_2}{b(P_2)}$$

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9 Spence does not mention this possibility. It seems implausible to suppose that individuals can choose only success or failure with certainty.

10 As in Spence, individuals are assumed to maximize expected returns; they are risk neutral.

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Note that when $P_2 = 1$, $\frac{P_2}{b(P_2)} = 1$. Similarly, the more productive must all choose to enter, the condition for this being

$$(5) \quad 2P_1 + 1(1 - P_1) - a(P_1)\hat{E} > 1$$

$$\text{or } \hat{E} < \frac{P_1}{a(P_1)} .$$

More than this, they must opt for perfect certainty ($P_1 = 1$); for otherwise, some of the more productive will fail and the firm's beliefs disconfirmed. When $P_1 = 1$, $\frac{P_1}{a(P_1)} = 2$. The necessary condition for a full signalling equilibrium is, thus,

$$(6) \qquad \frac{P_2}{a(P_2)} < \hat{E} < \frac{P_1}{a(P_1)}$$

Whether or not a full screening equilibrium occurs clearly depends upon the shape of the signalling cost functions. Consider first the case of constant marginal costs. Given our previous assumptions and further assuming that $a(0), b(0) = 0$, it must be that $C_1 = \frac{P_1}{2} E$ and $C_2 = P_2 E$. The net return to the more productive when they signal is from 6)

$$(7) \quad P_1 + 1 - \frac{P_1}{2}\hat{E} = P_1 [1-\tfrac{1}{2}\hat{E}] + 1$$

which is clearly maximized at $P_1 = 1 - \frac{1}{2}\hat{E}$ must be positive from (5). The less productive will never enter the system since, for them, the return is from (4).

$$(8) \quad P_2 + 1 - P_2\hat{E} = P_2 (1-\hat{E}) + 1$$

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which is maximized at $P_2 = 0$ since $1 - \hat{E} < 0$. Thus, for constant marginal cost functions, a full screening equilibrium is obtained as before.

The same result holds for decreasing marginal signalling cost functions. For this case (7) becomes

$$(7') \quad P_1 + 1 - a(P_1)\,E = P_1\left(1 - \frac{a(P_1)}{P_1}\hat{E}\right) + 1.$$

Since $a''(P_1) < 0$, letting $\frac{P_1}{a(P_1)} = f(P_1)$ it must be that $f'(P_1) > 0$. Thus (7') can be written as $P_1\left[1 - \frac{1}{f(P_1)}\hat{E}\right] + 1$. But $\left(1 - \frac{1}{f(P_1)}E\right)$ must be positive by (6) and an increasing function of P_1 so that increases in P_1 must raise earnings for any level of E up to $f(1)$. Thus the optimal choice is $P_1 = 1$ and E must be less than two for equilibrium. Similarly, in order to insure that no less able person attempts to purchase education, $\hat{E}$ must be larger than unity since the maximum value of $\frac{P_2}{b(P_2)}$ is unity. Thus the condition for a signalling equilibrium is again given by (3).

However, suppose there are increasing marginal costs. For the less able, let $\frac{P_2}{b(P_2)} = g(P_2)$ where $g'(P_2) < 0$. In order for no β_2 type to desire entry, the lower bound for E must be set at the maximum value of $g(P_2)$ since, otherwise, there will exist a positive probability at which it will pay them to purchase an education lottery. Since $\frac{P_2}{b(P_2)}$'s maximum value is greather than unity, $\hat{E}$ must be greater than this number in order to be an effective signal. For the more able, let $\frac{P_1}{a(P_1)} = h(P_1)$ where $h' < 0$. One can easily find examples for which there exists no value of $\hat{E}$ within the range given by (3) for which the optimal choice is $P_1 = 1$. There exists no signalling equilibrium for this

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set of priors even though signalling costs are negatively correlated with productivity. Suppose for example $h(P_1) = \frac{2}{P_1}$ $(a(P_1) = \frac{1}{2} P_1^2)$. Then net income is maximized at $P_1 = \frac{1}{\hat{E}}$ which implies that the more productive will choose to spend $C_1 = \frac{1}{2} E$ only for $\hat{E} < 1$ which does not lie within the equilibrium range. In fact, for the family of signalling cost curves given by $a(P_1) = \frac{1}{2} P_1^k$ this result is valid.

Obviously, all that this exercise has demonstrated is that, for the set of conditional beliefs predicting full (perfect) screening, there are some conditions (sufficiently increasing marginal cost) under which a "perfect" signalling equilibrium may not result. It can be shown that the result holds for other sets of beliefs, but proceeding in this manner does not constitute a proof of non-existence. However, the example does illustrate the difficulty in obtaining signalling equilibria in a more complex setting; for, the choice of success probabilities depend upon $\hat{E}$, and it is this choice which determines whether beliefs are confirmed. If each $\hat{E}$ corresponds to a different choice of the probability of success (as it does in the above sample), the firm's beliefs would have to correspond explicitly to this choice as the success probabilities determine unique schooling-ability distributions. Thus, in this case, multiple equilibria are impossible.

Spence discusses several other signalling situations. For example it is shown that the phenomenon may coexist with education being somewhat productive although if it is too productive relative to the differences in signalling costs, all individuals will select the same schooling level. It is also demonstrated that identification need not be perfect. This arises when signalling costs are only imperfectly correlated with productivity, the imperfection arising due to taste differences or family wealth differences. In this case, some high

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productivity persons self-select themselves out of higher education and are therefore associated with low-productivity types. The reverse may also occur. As long as the correlation between productivity and signalling costs is negative, signalling equilibria may exist. However, the more imperfect the signal, the lower is its return.

The major point of these educational screening models is that the empirically observed private rates of return to schooling can be generated within a framework of incomplete information without relying on human capital augmentation. The models consist mainly of existence proofs and then only under highly uncomplicated situations. It is difficult to see how the existence of signalling equilibria as defined could be established in a world in which individuals differ in their productivities across industries and occupations, firms have different experiences and thus different expectations, schools make mistakes etc. But, one needn't show the existence of signalling equilibria to realize that the informational phenomenon may exist. After all, firms must realize that they may obtain a different productivity-schooling distribution than that which would be perfectly consistent with their priors. Signalling equilibria are probably flexible with respect to new market experiences. To repeat, the real question posed by these models is concerned with the degree to which credentials serve as information sources as opposed to the degree to which they signal productivity differences which are outcomes of the schooling process. That situations in which education plays an identification role can be shown to exist is not surprising however ingenious the models. That this is its only function as previously argued, appears implausable.

Suppose that education's major function is informational. What effect does this have on the social desirability of a given educational

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investment? The question clearly hinges on the social value of the information conveyed and upon the cost of developing cheaper information sources of equal quality. Clearly, in a pure screening world, individuals would never choose to obtain formal schooling if they could derive the same benefits from a less costly device. More realistically, the extent to which private schooling investments would fall would depend upon the screening-productivity mix.

To illustrate, consider the following example drawn from the model developed in Chapter II. Suppose there are two types of individuals and two schooling classes, denoted by E_H and E_C. The distribution of skill within the two schooling groups are assumed to have as their respective means and variances μ_H, μ_C and σ_H^2, σ_C^2. Assume that $\mu_C > \mu_H$ and the variance-mean ratios are equal so that schooling's private return is related only to the difference in means. The social value of schooling depends upon how much of the difference $(\mu_C - \mu_H)$ is accounted for by skill endowments as opposed to skill-formation.

In the models previously examined, the information itself has no social value - in fact, the social return is negative. If education imparted no skills, from a social perspective, the resources used in the acquisition of schooling would be a social waste. Since marginal products are assumed constant, gross social output is $k\mu L$ where L is the inelastically supplied labor stock, μ is the population's mean skill level and k is the constant marginal product of skill. Net social output is $k\mu L - CL_C$ where C is the output cost per educated individual and L_C the number of such individuals. The optimal social investment in education clearly occurs at $L_C = 0$, where no individual invests in schooling, since gross social output is itself unaffected by the number of educated individuals.

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Assume for the moment that education is acting as a perfect screen so that $\sigma_H^2 = \sigma_C^2 = 0$. Let s_A be the skill level of type A individuals and s_B that of type B with L_A and L_B being their respective numbers and $s_A > s_B$. With a perfect screen, the subscripts also stand for schooling classes, where $\mu_C = s_A$, $\mu_H = s_B$, $L_C = L_A$ and $L_H = L_B$. Gross social product with constant marginal products is simply $k\mu_H L_H + k\mu_C L_C = kS$ where S is the aggregate skill in the economy. Note that for any given number of firms, the distribution of skill over firms is unimportant with respect to aggregate performance. Now assume that firm output is a function of a single aggregate skill as described in the previous chapter and suppose there are N firms each employing L workers. For the i^{th} firm actual output is

$$(9) \quad Y_i = F(S_i, K) = F(\bar{s}_i L, K)$$

where $\bar{s}_i$ is the mean skill level obtained by the i^{th} firm from a random sample of L workers. Taking a second order approximation around $\bar{S} = \mu L = \frac{S}{N}$, the expected aggregate skill input, yields

$$(10) \quad Y_i = F(\mu L, K) + (\bar{s}_i - \mu) L F_{\bar{S}} + \tfrac{1}{2} (\bar{s}_i - \mu)^2 L^2 F_{SS}$$

where F_S and F_{SS} are the first and second-order partials evaluated at $\bar{S}$. Aggregate output is therefore

$$(11) \quad \sum_{i=1}^{N} Y_i = NF + \tfrac{1}{2} L^2 F_{SS} \sum_{i=1}^{N} (\bar{s}_1 - \mu)^2.$$

The second term in (10) is zero as total skill must be exhausted. Since $F_{SS} < 0$, gross output is maximized where $\Sigma(s_i - \mu)^2 = 0$, i.e., where each firm obtains the identical sample mean skill level. Assuming

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a potentially perfect screen, it can easily be demonstrated that

$$(12)\quad L^2 \sum_{i=1}^{N} (\bar{s}_i-\mu)^2 = (\mu_C-\mu_H)^2 \sum_{i=1}^{N} (L_{Ci}-\frac{L_C}{N})^2$$

where L_{Ci} is the i^{th} firm's labor input obtained from schooling class E_C and $\frac{L_C}{N}$ is the number of L_C workers the i^{th} firm would obtain if the L_C workers were equally distributed over firms. When firms do screen, each firm samples the same number of workers from within a schooling class. But, from (12), if $L_{Ci} = \frac{L_C}{N}$ for all i, aggregate output is maximized. The maximum social benefit from education's screening function is therefore

$$(13)\quad \tfrac{1}{2}\left[\frac{}{SS}\right] (\mu_C-\mu_H)^2 \sum_{i=1}^{N} (L_{Ci}-\frac{L_C}{N})^2,$$

as one can further demonstrate that as education becomes a less perfect screen, its social benefit declines (see Appendix B). In this case, even as firms employ the same factor proportions, variations in aggregate skill will persist as within group skill variances remain. The limiting case in which screening has no social value occurs where the mean skill level of the two schooling classes are identical so that sampling within groups is tantamount to sampling the total population. It should be clear that the return to screening is due to the elimination of between group skill variance; it is as if each firm samples from a total population with a smaller skill variance.

In the previous models, the private and social returns to schooling had to diverge for any skill distribution containing a positive ability component. But, in the above model, there will exist some less than full productivity effect which will equate the two returns. The social return may be positive even with a zero productivity effect if the cost of education is smaller than the expression given by equation (13). Note that the social return falls with reductions in screening efficiency

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From (13), it is easily seen that increasing the difference in endowments (given a perfect screen) increases education's screening return with a constant population mean, i.e., a reduction in μ_H with an increase in μ_C. Suppose, however, that, with given endowments, education's productivity effect increases. Clearly, its social return rises as education adds to aggregate skill. But, it is also possible for education's screening return to increase; the effect depends upon the rate of decline in the marginal product of skill. If $F_{SSS} < 0$, the informational value of education must increase while if $F_{SSS} > 0$, its value may rise or fall depending upon the size of the productivity augmenting effect.[11, 12] Clearly, schooling has its maximum social return for any given schooling distribution where it is a perfect screen, and the difference in schooling class skill levels is solely due to skill formation - in this case, the social return exceeds the private return. If, as Stiglitz argues, screening efficiency and skill formation are joint products, education's gross social product may rise by more than the value of the additional skills produced by schooling.

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[11] An increase in schooling's productivity effect is assumed to increase $\mu_C - \mu_H$.

[12] This result follows from the fact that the screening return is larger, the more negative F_{SS} (see equation 11)) and the larger is $(\mu_C - \mu_H)^2$.

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Consider the introduction of a second aggregate skill input. Assume again N firms each employing L_1 workers to fulfill its aggregate skill requirement, S_1, and L_2 different workers to fulfill S_2. Moreover, to simplify the analysis, let us suppose that all individuals are equally productive in the second occupation, but that there are two skill classes as before with respect to S_1. Analogous to equation (11) one can derive the following expression for aggregate output.

$$(14)\quad \Sigma Y_i = NF(\bar{S}_1, \bar{S}_2) + \Sigma(\bar{s}_{1i} - \mu_1) L_1 F_{\bar{S}_1} + \tfrac{1}{2}\Sigma(\bar{s}_{1i} - \mu_1)^2 L_1^2 F_{\bar{S}_1 \bar{S}_1}.$$

Note that $\bar{s}_{2i} - \mu_2 = 0$ for all firms by assumption so that all other terms in the expansion vanish. More importantly, notice that the second term in equation (14) does not vanish as in the previous one skill input model. The reason is simply that the aggregate skill input obtained by each firm and thus the utilization of S_1 economy-wide depends upon the distribution of workers employed in each of the two occupations. There are, in this case, two returns to screening. The first, as before, is related to reductions in aggregate skill variation between firms. The second, however, refers to the proper allocation of workers within firms (see Appendix B). Clearly, there is a social gain to allocating individuals to their most productive uses (occupations). Total output is maximized where the more productive workers in occupation one are assigned to occupation one.

Arrow (2) demonstrates the existence of a positive social benefit to screening with a fixed coefficients production process. The basic framework is the same as above, except that the screening return is derived from altering the number of workers in each occupation so as to maximize output whereas in the model outlined above the number of

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workers in each occupation is fixed at both the firm and aggregate levels. With fixed coefficients, the return to screening is zero in the previous model as each firm is constrained to $S_2=\mu_2 L_2$ units of aggregate skill in occupation two. But, with some degree of aggregate skill substitutability, both return are relevant; there is a positive return with the constraint that each firm hire fixed numbers within occupations and a further return from permitting firms to alter their factor proportions, given the information. Equation (14) therefore yields an underestimate of the social value of screening for any level of screening efficiency. Extending the model so as to include more aggregate skill inputs with different degrees of screening efficiency attached to those inputs and allowing firms to adjust factor proportions as well as total factor employment unduly complicates the arguments without leading to further insights. The important point is that there exists a positive social benefit from screening even in the absence of a productivity effect and one which may positively interact with this latter effect.

The implications of these models can be evaluated only by an empirical examination. Although a wide range of studies exist on the schooling-earning relationship, few attempts have been directed toward discovering their link. Much of the work has been concerned with assessing the bias in schooling's private return which results from ignoring measures of ability and family background. The results have consistently found a minimal reduction in schooling's effect on earnings. (See Grilliches & Mason, Gintis). However, it would be erroneous to conclude from this that schooling is an input into the production of human capital rather than in identification device. The reason is that screening arises solely as a consequence of imperfect information.

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Schooling is simply a proxy for earnings producing skills (ability), at least during the early phases of an individual's career. If ability measures were perfectly correlated with productive skills but firms were unaware of an individual's ability (measure), schooling might still have a larger effect on earnings (over the life cycle), provided that schooling served an informational function. That these ability measures may only very imperfectly correlate with success in the job market is actually a peripheral consideration to the applicability of these studies to the screening hypotheses.[13]

One possible test of screening does emerge from these arguments. If educational attainment is being utilized as a screen, then its effects should be most pronounced at early stages in the life-cycle and should diminish over time (experience) as firms glean information about actual productivities from on-the-job performance. The same conclusion should apply to measures of what an individual learns in school if the knowledge itself has no influence on productivity and firms utilize these measures as screening devices. This is the tactic followed by Wise (24). Wise's null hypothesis, however, is "the absence of a significant relationship between academic achievement and job performance."[14] It is not surprising that this hypothesis can be rejected.

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13 Arrow mistakenly believes that it is the imperfections in the ability measures which detract from the usefulness of these studies when applied to the screening hypotheses.

14 D. Wise, Academic Achievement and Job Performance, Ford Foundation Program for research in University Achievement, Paper P-37, 1973, p. 3.

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Wise's data consists of biographical and salary information on approximately 1300 college graduates employed by a single large manufacturing company in 1968. All individuals had at least 3 years of experience in the firm and were no older than 30 at the time they were initially hired by the firm. The population was further restricted (by Wise) to persons with less than 23 years of experience. The resulting sample consisted of 967 individuals.

The earnings equation that was estimated is shown below:

$$(15) \quad s = e^{a} e^{rt} e^{\varepsilon}, \quad \ln s = a + rt + \varepsilon$$

where s stands for the individuals current salary, e^{a} is initial salary ($t=0$), r is the constant rate of increase in monthly salary between any two years, t is the number of years of experience in the firm and ε is a disturbance term. Both a and r are assumed to be functions of personal characteristics as given below:

$$a = a_o + a_i + b_j + dx_o$$

$$r = r_o + \alpha_{i+}\beta_j + \gamma_k + \sum_{\ell=1}^{9} \delta_\ell x_\ell$$

where $\Sigma a_i, \Sigma b_j, \Sigma\alpha_i, \Sigma\beta_j, \Sigma\gamma_k = 0$

and

a_o = Constant

a_1 = effect of having a BA degree at initial hiring

a_2 = effect of not having a BA degree at initial hiring

b_1 = effect of an engineering or science major

b_2 = effect of a liberal arts (or other) major

b_3 = effect of business major

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x_o = years of experience prior to initial hiring

r_o = average rate of salary increase

$\alpha_1, \alpha_2, \ldots, \alpha_6$ = effect of college quality (Astin index)

$\beta_1 \ \beta_2 \ldots, \beta_4$ = effect of grade point average (3.5-4.0, 3-3.49, 2.5-2.99 less than 2.5)

$\gamma_1, \gamma_2, \ldots, \gamma_4$ = effect of rank in MA program (top 5%, top 1/3, lower 2/3, no MA)

$x_1, x_2, \ldots, x_5$ = measures of job satisfaction and socioeconomic background.

(See Wise for a fuller discussion of these variables).

The preliminary analysis does not allow interactions between any of the variables. Since Wise reports interaction terms to be insignificant, attention will be restricted to the simpler specification. Results are duplicated below in Table I with the x_L, L=1.., 5 variables omitted.

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TABLE 1

EARNINGS REGRESSION

Variable	Estimated Coefficient	Standard Error	F - Statistic (null hypotheses: equal effects)
Constant	6.70356		
a_1	.02591	(.01029	5.766
a_2	-.02591	(01029)	
b_1	.03879	(.00764)	16.018
b_2	.01340	(.00956)	
b_3	-.02539		
x_o	.01647	(.00315)	
r_o	.04501	(.00171)	
α_1	.01085	(.00308)	
α_2	.00234	(.00119)	10.718
α_3	.00122	(.00147)	
α_4	.00183	(.00091)	
α_5	-.00431	(.00116)	
α_6	.00827		
β_1	.00777	(.00131)	22.179
β_2	.00055	(.00087)	
β_3	-.00245	(.00073)	
β_4	-.00587		
γ_1	.01241	(.00311)	11.398
γ_2	-.00017	(.00182)	
γ_3	-.00504	(00193)	
γ_4	-.00720		

Source: Wise(Table 2).

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The rate of salary increase clearly rises with college quality and grade point average. Wise (following Astin by whom the index is devised) assumes that the quality of the college attended reflects the average ability of the entering class while grade point average, I presume, reflects one's mastery of subject matter. Wise argues that if schooling does nothing to enhance productive attributes, then there should be no persistent effect of grade point average on earnings. Moreover, since he finds the effect of GPA to be important at all ability levels (no interaction) and he suggests that the greater the quality of college attended the more homogeneous are the individuals with respect to ability, he rejects the conclusion that performance in school is merely used to identify the more able. He also rejects the hypothesis that grade point average is merely a proxy for affective traits which influence productivity on the basis that high school performance, which should be an equally good proxy for these attributes, is insignificant and does not reduce the affect of college performance (GPA) when also used in the regression analysis.

However, Wise ignores on-the-job training as a component of earnings. If GPA is positively correlated with the amounts (measured in time equivalents) an individual invests on the job, profiles of $\ln s$ (and s) will diverge (see Mincer (13)). That this is occurring here to some degree is evidenced by the finding that neither GPA nor CQ have any effect on starting salaries. Wise contends that this is due to the belief by firms that they would create morale problems by differentiating between individuals in this way. It is difficult, however, to sustain this view assuming competitive markets. Of course GPA may reflect, in part, the rate of return to post-schooling investments

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which, if causally related to GPA, should be included in the return to schooling.

The problem is circumvented to some extent by segmenting the population by undergraduate major and by job function. One would expect the variation in post-school investment behavior to be smaller within these classifications than across the whole population. But Wise does not report the effects of GPA or CQ on initial salary for the different groups. In any event, GPA is found to have a positive and significant impact on the rate of salary increase for engineers and business majors but not for liberal arts majors although, for the latter, the sample size was comparatively small. The same conclusion follows when one looks at regressions by function - those in which liberal arts majors are most prevalent yield smaller GPA effects. Whatever liberal arts majors do learn seems to be less relevant to the job they perform.

A further result concerns the effect of a Master's degree on salary. As is seen from the table, merely obtaining a Masters has no appreciable effect on earnings unless the individual graduates in the top 1/3 of the class. This holds true for both engineers and business majors. It would have been interesting to see the effect of having a Masters degree on initial salary especially for those in the botton 2/3 of their class, but Wise notes that most graduate training was obtained while working. Wise argues, although not explicitly, that Masters programs are, at least, potentially productivity augmenting, the effect depending upon an individual's performance. But, from a social perspective, the question concerns not the potential but rather the actual productivity gain. Moreover, the larger rate of salary increase could, in part, be due to a jump in salary at the time the degree was granted which might

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be construed as an identification effect captured by all individuals obtaining the degree.

As long as one is willing to accept Wise's interpretation of the effects captured by CQ and CPA, it appears that colleges do impart productive skills although an individual's college major and the function performed within the firm are also important. To the extent that CPA itself has an ability component, along with measuring accrued knowledge, the results are weakened. Also, to the degree that earnings profiles differ due to on-the-job training investments, the results may be confounded. Furthermore, accepting the weak hypothesis that colleges have a statistically significant affect on productivity does not exclude the possibility that a statistically significant component of the return is due to screening.

Taubman and Wales, on the other hand, attempt to test for the existence of a screening effect. According to the authors, screening is said to occur when individuals, due to their lack of educational attainment are restricted from entering occupations in which their marginal products are greatest. In other words, if individuals were free to choose the occupations they entered at a wage commensurate with their true marginal products and not based upon the average productivity of the individuals with the same schooling level, a greater proportion of less educated would be found in higher paying occupations.

What T & W do is to estimate earnings as a function of education, measured ability, father's education, age, and other characteristics within broad occupational categories from the NBER - Thorndike sample of any airforce pilot and navigator candidates in 1943 (see Chapter IV for a fuller discussion of this data set).

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From the occupational regressions, potential earnings of individuals in occupations other than their own are estimated. The residual variances are used as estimates of the dispersion around an individual's potential income and the disturbances are assumed to be uncorrelated across occupations. To illustrate the application of this approach in a two occupation world, let $\bar{Y}_1$ and $\bar{Y}_2$ be the mean incomes obtained for a given schooling class from the regressions equations

$$Y_i = \alpha_i \quad x_i + U_i \quad i=1, 2$$ where α_i is a vector of coefficient and X_1 the vector of independent variables including those cited above. Let σ_1^2, σ_2^2 be the variance of the disturbance terms assumed to be normally distributed with zero means. If $\bar{Y}_1 = \bar{Y}_2$, then half of the population can be expected to be found in each occupation. If $\bar{Y}_1 < \bar{Y}_2$, then the proportion expected in occupation one will decline for any given variances; the greater is $\bar{Y}_2 - \bar{Y}_1$ the smaller this expected proportion.

The resulting expected and actual occupational distributions by education are duplicated in Table 2 . The regressions upon which these results are based are as previously described, except that occupations were grouped with individual occupational dummies inserted. The groupings were (1) professional, sales and technical; (2) blue collar, white collar, and service; (3) managerial. No interactions were used so that earnings merely shifts up or down for occupations within each broad classification.

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TABLE 2

ACTUAL AND EXPECTED OCCUPATIONAL DISTRIBUTIONS

	High School				Some College				College Graduate			
	Actual		Expected		Actual		Expected		Actual		Expected	
Prof	1.5		9.5		5.8		14.8		25.0		17.8	
Tech	11.5	20.6	21.0	52.5	9.6	24.8	19.1	55.7	2.8	36.6	14.1	55.7
Sales	7.6		22.0		9.4		21.8		3.8		25.5	
Blue Collar	28.6		1.3		10.2		.8		1.8		.9	
Service	6.8	38.7	1.4	3.2	3.8	26.5	1.2	2.6	1.1	4.0	.9	2.2
White Collar	3.3		.5		2.5		.6		1.1		.4	
Managerial	40.6		42.4		58.8		39.8		59.4		38.3	

Source: Taubman and Wales (Table 1, Chapter 9).

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T & W conclude from Table II that: "In general then, under the assumptions of free entry and income maximization, very few people at any education level in our sample would choose the blue collar, white collar, or service occupations."[15] The fact that high school graduates predominate in the occupations is taken as evidence of educational credential requirements. They find more problematic the fact that in the higher paying occupations (Prof., Tech., Sales) the expected fractions always exceed the actual and resort to rather ad hoc explanations. After all, under a screening proposition, why would college graduates be restricted from entering those occupations which maximize income if they are indeed the preferred group? Although T & W realize that the most important qualification to this approach concerns the assumption that there are no unmeasured occupation-specific skills which are correlated with education, they fail to realize that this in itself makes it impossible to distinguish between the two hypotheses. That occupation-specific skills are important appears obvious from Table 2. The expected fractions within the three occupational groupings are almost identical for the three schooling classes. Their results imply that the same proportion of high school graduates would be found in the prof., tech., and sales class as college graduates, and the same proportion of college graduates would be found in the blue collar, white collar, service occupation as high school graduates. It seems clear that high school

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15 P. Taubman and T. Wales. "Education as an Investment and Screening Device". Mimeographed. New York: National Bureau of Economic Research, 1972, p. 9-19.

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graduates who are in the first occupational category are not identical to those in the second (even after controlling for other characteristics), and, thus, to extrapolate the earnings potential of the latter from actual earnings of the former must lead to spurious results. The result in the first occupation set for college graduates is further evidence that these regressions are ignoring some specific characteristics which are more important in some occupations than others. All that T & W have demonstrated is that there exists a high correlation between education and occupation but have not demonstrated, as they intended to do, that this relationship is based significantly on entry barriers. The fact that their results are consistent with a screening interpretation does not aid in distinguishing between the two views. Moreover, even if the actual distributions are those which would obtain under strict income maximization, the question would still remain as to whether schooling produced those occupational skills or merely signalled their endowment. The test conducted by T & W sheds no light on this issue.

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CHAPTER IV

EMPIRICAL TESTS OF THE SCREENING HYPOTHESIS

The proposition advanced in the preceding chapters is that the private rate of return to schooling may be interpreted as derived from the purchase of a label which serves to identify or signal productivity endowments rather than, as in the usual view, to directly enhance productivities. The empirical problem is to disentangle these two effects and ultimately to measure their relative importance. The attempts reviewed in Chapter III were much more modest in scope as they aimed solely at demonstrating the existence of one or the other effect. Even these results were not free of ambiguities. The more ambitious undertaking, although more desireable for social policy, must await the resolution of these simpler issues. Possibly, the question is unanswerable when posed in a general form given the wide variety of occupations and job tasks associated with any level of educational attainment.

This chapter will attempt to serve two functions. First, several tests for the existence of a screening return will be furnished. Second, by exhausting some of the more obvious procedures, future research, it is hoped, can proceed in somewhat different directions. The major difficulty with many of these empirical formulations is that they are based upon life-cycle earnings relationships whereas the theoretical foundation is couched primarily in static terms. Implications from this static framework can only naively be extended past the initial phase of work experience.

One further issue should be raised before proceeding. Although seemingly semantic, it has nevertheless led to confusion. Screening has been used to describe a situation in which educational institutions

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fail to impart job relevant skills. Yet, the term has also been used in an informational context in the sense that if there exist real productivity differences across schooling classes which can be discerned by firms, educational attainment will be utilized as a basis for employment. However, the latter may or may not be related to the former; whether schools produce useful labor market skills or whether they merely segment the population into groups which differ in their skill endowments (or both), group differences will emerge and useful information imparted. Any demonstration of schooling's informational role is only peripheral to the former issue.[1]

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[1] A simple test for schooling's informational function can be constructed. To the extent that schooling is the predominant screen, i.e., other devices do not, in conjunction with schooling, perfectly predict productivities, the correlation between schooling and earnings should be greatest at initial or early levels of experience. Thereafter, as firms learn about actual productivities and the variance in earnings within schooling classes rise, the correlation should continually decline. However, this result may be confounded by post-schooling investment behavior. In fact, Mincer finds a rising correlation until the "overtaking" experience level (approximately the first decade) followed by a rapid decline (see Mincer (13), page 57). When I performed the same calculations for the Thorndike sample discussed in the text, a pattern of rising correlations throughout the life-cycle was found. Although ln variances in earnings increase with experience, the marginal return to schooling increases at a faster rate, causing this result. But, the manner in which the sample is constructed leads to quite different schooling distributions within experience classes, confusing the issue. Whether this result is peculiar to this sample or general to longitudinal as opposed to cross-sectional data sets is clearly an issue for future research.

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Before proceeding with specific tests of the screening hypotheses, some observations about the general explanatory power of this framework should be raised. Without detailing the substantial literature on the role of education in economic growth, it is clear that these studies raise rather serious doubts about the importance of the screening view. If one is to accept the notion of only a limited productivity effect of schooling, a reconciliation with these studies is imperative. In a recent survey of the human resources area, T. W. Schultz states that "..... it is now established that the omission of the improvements in the labor force associated with education accounted for a large underestimation of the increases in the effective labor force, as Denison as well as Jorgenson and Griliches have shown".[2] Although one might quarrel with the force of this statement, it is, I believe, difficult to deny its thrust. The implication is not compatable with a world in which schooling serves mainly an informational function. In the extreme view, with a relatively stable "ability" distribution of successive cohorts

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2 T. W. Schultz, Human Resources, NBER, New York, 1972. Distributed by Columbia University Press, New York and London. The two references are: Edward F. Denison, "The Sources of Economic Growth in the United States and the Alternatives Before Us", New York Committee for Economic Development, 1962.
D. W. Jorgenson and Zvi Griliches, "The Explanation of Productivity Change," Review of Economic Studies, 34, July 1967.

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of labor force entrants, there would, in fact, be little or no correlation between productivity growth and educational attainment.[3] Moreover, there is nothing inherent in screening models which would predict schooling levels to rise as they have. In the context of Spence's model, one wonders about the nature of the forces which would continually disturb the equilibrium signalling pattern and concomitant educational distribution so as to displace schooling levels upward over time. Any serious consideration of schooling's identification role as a major source of its private return would have to address these issues. Although the theme will be repeated throughout this chapter, it is important to note that the screening argument as a general proposition appears to add little to the productivity augmenting view of the schooling-income relationship.

The screening model presented in Chapter II demonstrated that those with more schooling will initially command a higher wage than those with less schooling if their mean skill level (μ) is larger, their variance-mean skill ratio (σ^2/μ) is smaller and/or if firms are relatively more certain as to the average level of their productivity ($\hat{\sigma}^2/\mu^2$) being the relevant parameter). Consolidating the latter two, several tests are

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[3] It is possible that along with increasing educational levels there has been an improvement in schooling's sorting function which, given the discussion in Chapter III, has augmented aggregate output. There is, however, no empirical evidence available which supports this contention. In fact, a test was performed for this purpose. If schooling is becoming, over time, a more perfect sorting device, one would expect to find larger within-schooling group variances in earnings within the same experience class for older cohorts. However, some rough calculations I have performed of ln variances from the 1960 and 1970 census do not elicit any discernable pattern.

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considered for the components, the mean effect and the variance effect. Since most of the tests are performed with the NBER-Thorndike population,[4] a general description of this data set follows.

The sample consists of approximately 5,000 air force pilot, navigator and bombadier candidates in 1943. In 1955 Thorndike and Hagen sampled 17,000 of these men and collected information on earnings, schooling, job experience and other socioeconomic variables including numerical scores on seventeen tests administered in 1943 which purport to measure various types of abilities ranging from manual dexterity to abstract problem solving capabilities. The NBER resampled a subset of these in 1969 and again in 1971 updating data on job histories and socioeconomic characteristics. Specifically, the data includes information on jobs held in five separate time intervals: 1945-1952, 1953-1957, 1958-1962, 1963-1966, and 1967-1970.[5] Data on jobs held in years other than those corresponding to the interview years are retrospective.

The sample is composed primarily of individuals of high ability and excellent health. All individuals are at least high school graduates and a majority have an undergraduate degree or some graduate training. Ages, as of 1969, range from 42 to 55. Therefore, for many, employment and schooling were interrupted by the war.

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4 I am indebted to Lee Lillard for his aid in using this data set.

5 Initial job, which may have occurred prior to W. W. II is also reported.

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To obtain accurate estimates of work experience, the population was restricted to those individuals whose initial job occurred after military service and in particular within the 1945-1952 interval. Experience is simply calculated as the difference between a reported job year lying within any of the five periods and the initial job year; it is, thus, definitionally zero for the initial job. Further exclusions were those individuals with extended military service (any who remained in the military after 1945), civilian pilots, the disabled and the unemployed. The constructed sample consists of 7893 separate experience-earnings points for those engaged (as of their last reported job) as private wage and salary workers and 1906 observations for the self-employed.[6] The reason for this dichotomy will become apparent.

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6 There were several possible ways to assign observations to one or the other class. Each reported job irrespective of the individual could have been assigned to the reported class. But, experience is defined cumulatively over each individual's work history and may not have the same impact on earnings for each of the two employment states. A second possibility would have been to choose individuals who maintained the same status throughout. As an approximation to this latter method, individuals were assigned to a given class on the basis of their last reported job. Of the 1906 observations for which the last job was in self-employment, 36% would also have been assigned to self-employment if, instead, the first and last job had been matched. The comparable figure for private wage employment was 92% of the 7893 observations. Regressions were run for those individuals whose class was the same on both the first and last job. Since many individuals did not report intermediate jobs, the sample sizes would have been severely restricted if further constraints were utilized. Results are qualitatively the same. See Table C.9 as contrasted with Table 1.

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Probably the more important question concerns the relationship between average productivity differences and schooling, the mean effect. Recall that the private return to schooling is solely a function of the additional skills associated with the more schooled group (ignoring variance returns) and will be the same, according to the models presented in the previous chapters, regardless of the mix between skill endowment and human capital acquired through schooling.

Using the NBER-Thorndike sample, earnings profiles were estimated for both private wage workers and for the self-employed. Table 1 reports the results for several regression specifications (see page 93 for a discussion of these formulations). The dependent variable in this and all other tables is the natural logarithm of earnings (in 1958 dollars) S is schooling level, P is experience, and A is an IQ-type ability measure.[7] Since the relevant hypotheses concern coefficient equality as between the self-employed and private wage populations, the regressions in Table 1 (and all following tables except where noted) are from the pooled sample. Each coefficient represents the partial effect of a given variable for one or the other sample. Given the variance-

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7 The ability measure is a composite of the seventeen tests. It was constructed by Al Beaton of the Educational Testing Service.

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covariance matrix of coefficients, t-tests may be performed to test for equality of single coefficients as between the two samples.[8] Descriptive statistics are given in Tables C.1 and C.2 in Appendix C.

Consider the effect of additional schooling for the two worker classes given in Table 1, equation 1. It is seen that the marginal return to schooling is larger for the self-employed at all experience points. The same result is apparent when schooling effects are averaged over all life cycle points (see equation 2 or 3). A joint test was performed on S and SP to determine whether the difference was statistically significant between the two groups. The two coefficients were constrained to be equal across the samples while all others were allowed to vary. The F-value obtained was 9.6 which is greater than the appropriate F-statistic ($F_{2,9785}$). Schooling, therefore, has a differentially larger impact on earnings among the self employed. Considering the screening models, there is no incentive for the more productive of the self-employed to use schooling as an identification

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8 Letting $Y_1 = X_1 \beta_1 + u_1$ and $Y_2 = X_2 \beta_2 + u_2$ refer to the separate regressions for the two worker classes, the pooled regression is of the form

$$Y = \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \end{bmatrix} = \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} = X\beta + u$$

where Y_1 is n x 1, Y_2 is m x 1, X_1 is n x k, Y_2 is m x k and β_1 and β_2 are k x 1.

See Fisher (6) for a discussion of hypotheses testing when some coefficients are constrained to equality.

TABLE 1

EARNINGS REGRESSIONS FOR PRIVATE WAGE AND SELF-EMPLOYED WORKERS: ALL OCCUPATIONS

Coefficients (t-values in parentheses)

	(1)		(2)		(3)	
	Private	Self-Employed	Private	Self-Employed	Private	Self-Employed
S	-0.0228 (6.35)	-0.0144 (2.20)	0.0284 (12.68)	0.403 (5.49)	0.0228 (9.92)	0.0397 (9.15)
P	0.0031 (1.70)	-0.0107 (1.21)	0.0782 (38.52)	0.0744 (18.16)	0.780 (38.61)	0.0744 (18.24)
p^2	-0.0012 (13.96)	-0.0008 (4.26)	-0.0014 (15.85)	-0.0010 (5.48)	-0.0014 (15.86)	-0.0010 (5.50)
SP	0.0043 (16.12)	0.0053 (10.80)	-	-	-	-
A	0.0055 (1.27)	-0.0081 (0.93)	-	-	0.0269 (9.81)	0.0037 (0.65)
AP	0.0020 (6.06)	0.0011 (1.65)	-	-	-	-
Intercept (a)	8.7123 (153.87)	.0291 (0.24)	7.9083 (221.13)	-0.0114 (0.14)	7.9919 (218.38)	-0.0858 (1.10)
R^2	.5225		.4927		.4977	

(a) The self-employed intercept is the difference between the actual self-employed intercept and the private wage intercept given to the left. Insignificance of the coefficient implies equality of the constant term in the two samples.

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device. If formal schooling has only a small productivity enhancing effect, it should be most apparent with respect to this group. Regardless of other considerations, the self-employed can earn at most only the market's valuation of their marginal product. That the schooling effect for the self-employed is comparable to that of the private class of workers is a clear indication of schooling's value. The endowment argument inherent in the screening view appears to add little to the productivity augmenting view of schooling's return.

It could be argued that the more productive among the self-employed are the ones who obtain more schooling and, thus, would earn more regardless of their educational attainment. However, an attempt was made to control for ability differences and, in any event, it is not clear why the more richly endowed would be more prone to engage in further schooling (after military service) unless they perceived some reward (which must be due to skill augmentation rather than identification).

One obvious modification is to delete the professional class since it is, in many instances, subject to public screening through occupational licensure. Restricting attention to the managerial class, which is basically the only other occupational category in which the self-employed are found, does alter the schooling effect.[9] However, interpreting the schooling coefficient within an occupation as a marginal

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[9] The self-employed predominate in the managerial and professional occupations accounting for 83% of the observations. The comparable figure for the private wage class is 60%.

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return to schooling in the usual sense is inappropriate given that the schooling and occupational choice decisions are probably not mutually exclusive. For the purpose at hand, a comparison between worker classes can, however, still be made realizing that it holds only for those who have chosen to enter the occupation and not for the entire population. Regressions are reported in Table C.4. The overall schooling coefficient (equation 2 or 3) is, in magnitude smaller for the self-employed; also, the schooling effect in equation (1) is less at all experience points within the sample range. However, these differences are not "significant".[10]

Similar reasoning applies to the effect of college quality on earnings as between the two groups. If the quality of college attended is used as a screen and merely serves a classificatory function, its effect should be less pronounced on the earnings of the self-employed. To facilitate the comparison, the subsample of college graduates (those having exactly 16 years of schooling) was chosen. Other sample restrictions are maintained. The regression equations are presented

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[10] A joint test on S and SP reveals that the schooling effect does not significantly differ between the two groups. The F value was 1.5. Also a t-test was performed on S alone for equation (3) in Table C.8. The t-value was 1.55.

TABLE 2

COLLEGE QUALITY REGRESSIONS FOR COLLEGE GRADUATES: ALL OCCUPATIONS

Coefficients (t-values in parentheses)

	(1)		(2)	
	Private (3,012)	Self Employed (688)	Private (3,012)	Self-Employed (688)
P	.0774 (13.95)	.0715 (6.01)	.0878 (26.60	.0873 (12.90)
p^2	-0.0016 (10.77)	-0.0012 (4.01)	-0.0016 (10.74)	-0.0012 (4.02)
Q	.0121 (1.01)	.0450 (1.75)	.0338 (4.54)	.0770 (4.70)
QP	.0021 (2.31)	.0032 (1.61)	-	-
A	.0029 (.40)	-0.0077 (.53)	-0.0002 (.03)	-0.0121 (.86)
AP	.0015 (2.77)	-.0006 (.53)	.0018 (3.42)	-0.0001 (.14)
Intercept	.0665 (.46)	8.2106 (63.08)	.1197 (1.26)	8.0518 (93.96)
R^2	.5631		.5622	

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in Table 2 below where Q represents the college quality variable and other symbols are as previously defined.[11]

Comparing the overall quality effect (averaging over experience points), it is observed that the self-employed do benefit more than private wage workers (see equation (2) in Table 2). Differences are in fact, "significant".[12] Similar results are obtained for the managerial class (see Table C.7). Descriptive statistics for the two worker classes for all occupations and for managers alone are given in Tables C.6 and C.7.

The obvious implication to be drawn from these tests is that human capital augmentation is responsible for the schooling effect observed in this sample. If the major portion of earnings differences between schooling classes could be accounted for by sorting, the self-employed would not earn as large a return from additional schooling nor would the greater knowledge gained from higher quality schooling have as large or as sustained an effect.

A comparison of average income of rural farm workers and urban workers at alternative schooling levels found in Welch (20) also supports the human capital view. The argument is basically the same as that with respect to the self-employed - private wage comparison made above since the rural farm class is predominantly composed of self-employed individuals.

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[11] The quality variable is a Gourman rating. Two such ratings were given, an academic and an overall one. The latter was used in the reported regressions. Results with the former are almost identical. The simple correlation between the two was .98 for both worker classes. In the tables and regressions the original rating was divided by 100.

[12] The t-value was 2.4.

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As Table 3 shows the percentage increase in earnings with increased schooling for the 45-54 year old age class reported by Welch rises more rapidly for rural farmers. The absence of a screening motive would preclude such a result if schooling did not augment productivities.

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TABLE 3[a]

Income in 1959 for Urban and Rural Farm Males, 45-54 Years Old, by Years of Schooling

Comparison for the 48 States	1-4 yrs.	12 yrs.	16 + yrs.
Urban Average	4,370	6,900	10,130
Rural Farm Average	2.780	4,900	7.600
Difference	1,590	2,000	2,530
Ratio	0.64	0.71	0.75

[a] Computed from data provided in the U.S. Census of Population, Source: Welch (20), Table 2.

One possible test for the variance component of the screening return can be made by comparing earnings profiles of different schooling groups. The argument can be made explicit with the assumption that post schooling investments are zero. If either or both of the variance components ($\frac{\sigma^2}{\mu}$ or $\frac{\hat{\sigma}^2}{\mu^2}$) are operative, the private return to schooling may be larger than that which is warranted by actual productivity differences. However, as firms learn about actual skill levels, wage rates will adjust to reflect performance. Wages should, thus, regress

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to their certainty levels. Notice that there is no necessity for the variance parameters to work in the same direction or even for their effects to favor the more educated. Nevertheless, the null hypotheses of an upward bias in schooling's private return due to variance effects will be maintained.

Recall that ambiguous theoretical results were obtained with respect to the effect of uncertainty on labor demand. Initial wage rates might be above or below that which would prevail under certainty. With perfect information ($\sigma^2 = \hat{\sigma}^2 = 0$) and in the absence of human capital accumulation after the schooling period, mean wage profiles for the two schooling classes, as depicted in figure 1, would be horizontal. Those with greater schooling would earn AC more at all stages of work experience. However, with variance effects favoring the more educated and assuming a negative impact of uncertainty on factor demand the wage profiles would be given by A'B and C'D where "full" learning occurs T years after initial work experience. As shown, this leads to convergent wage profiles over some range.[13]

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[13] These conclusions are not independent of the learning process. All that is being said is that the more educated will earn more relative to the less educated than is warranted by true productivity differences and that over time relative wage rates will begin to reflect this initial bias. If there are different rates of learnings about the two groups, there may be a period during which earnings diverge but convergence must, nevertheless, occur over some range.

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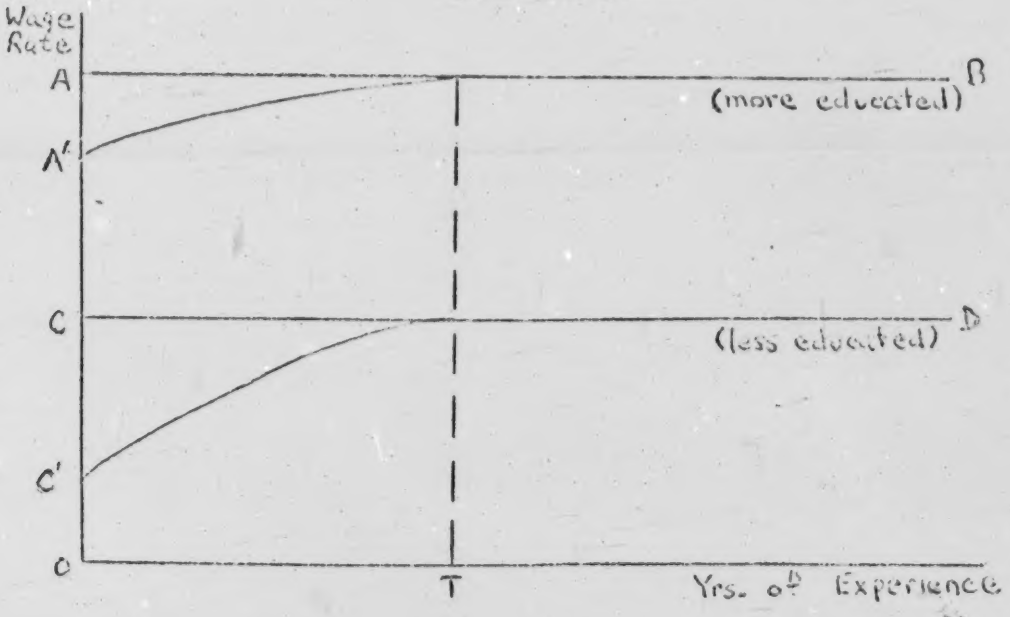
Figure 1. Wage - Experience Profiles with Imperfect Information by Schooling Class



Complications arise when there are opportunities for on-the-job training. If post-schooling investment behavior is systematically related to educational attainment, any degree of convergence or divergence can be elicited. If the more educated either invest more heavily at each level of experience, or if they earn a larger return per dollar invested, profiles will tend to diverge.[14] If this is the case, then

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14 The incorporation of learning into a human capital production model is clearly relevant to the shape of earnings profiles, but the issue is very complex. It is one possibility for extending screening models to a life-cycle context which might elicit more concrete testable implications.

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the variance effects, if they exist, will be discernable only if they outweigh the training effects.[15] The available evidence suggests the exact opposite; the variance return is overwhelmed by systematic investment patterns. For example, in Mincer (13) and Lillard (12), it was found that dollar earnings profiles diverge with increasing experience.[16]

The regression equation used to test for the existence of the postulated variance component is specified below. The form was chosen for the specific screening hypothesis rather than as a direct consequence of a formal theoretical construct. It is not particularly different from the usual types of earnings functions that have been used in other studies. All variables are as previously defined.

$$(1) \quad \ln Y = \alpha_o + \alpha_1 S + \alpha_2 P + \alpha_3 P^2 + \alpha_4 SP + \alpha_5 A + \alpha_6 A P + \mu$$

Mincer finds convergent ln Y profiles using the cross-sectional 1960 1-1,000 Census which he attributes to the more educated investing less "time" in job training relative to the less educated. Welch (23), however, perceives a vintage effect as the cause since those with more experience obtained their schooling in earlier years. The latter is, however, not possible in this sample, given the manner in which the sample is constructed. Experience levels do not correspond to specific age cohorts.

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15 For a complete discussion of the relationship between human capital accumulation and the life-cycle earnings distribution see Mincer (13).

16 Mincer uses the 1960 1-1,000 Census. Lillard uses the NBER-Thorndike sample described more thoroughly in the text.

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Since convergence implies declining earnings differentials between schooling classes with experience, a negative value for the least squares estimate of α_4 would be consistent with the screening view. Note that it would also be consistent with Mincer's human capital model. The ability terms are included to allow for the possibility that individuals of greater innate talent or initial "skill" invest more resources on the job or earn a larger investment return.

Regression results for private wage and salary workers are reported in Table 4. Descriptive statistics are given in Appendix C, Table C.1. Several different sample specifications were tried; the basic results are generally unaltered. For example, there are probably non-pecuniary returns or labor supply considerations which explain the fact that teachers by far have the highest average level of education yet rank only fifth (out of 8) with respect to earnings. Also, medical doctors, lawyers and other professionals are generally restricted in their schooling decisions and would not be subject to a variance return. The major effect of excluding these groups is to enhance the effect of schooling on earnings as shown in Table 4. Since labor supply variables were given only for the last job and extrapolations back to previous jobs would be highly subjective, no attempt was made to incorporate them into the analysis.

Concentrating on equations (3) and (5), it is seen that the percentage increase in earnings due to an additional year of experience is larger the greater is schooling; ln Y schooling class profiles fan out with experience. For example, from equation (6) at 5 years of experience an extra year of schooling is associated with a 1.5%

TABLE 4

EARNINGS REGRESSIONS FOR PRIVATE WAGE WORKERS (a)

Coefficient (t-values in parentheses)

	All Occupations			Excluding Teachers and Professionals		
	(1)	(2)	(3)	(4)	(5)	(6)
S	0.0284 (13.53)	0.0223 (10.61)	-0.0228 (6.80)	0.0519 (18.23)	0.0466 (15.60)	-0.0123 (2.62)
P	0.0782 (41.0)	0.0780 (41.29)	0.0080 (1.82)	0.0725 (31.11)	0.0724 (31.17)	-0.0125 (2.17)
p^2	-.0014 (16.91)	-.0014 (16.95)	-.0012 (14.94)	-.0012 (12.05)	-.0012 (12.07)	-.0010 (10.30)
SP	-	-	0.0043 (17.26)	-	-	0.0054 (16.00)
A	-	0.0269 (10.49)	0.0055 (1.36)	-	.0186 (5.73)	-.0026 (.5105)
AP	-	-	0.0020 (6.49)	-	-	0.0019 (5.14)
Intercept	7.9083 (236.39)	7.9919 (233.90)	8.7123 (164.84)	7.6131 (175.34)	7.6915 (169.40)	8.5784 (121.92)
R^2	.5009	.5078	.5331	.4725	.4756	.5084

(a) As noted, each individual could have reported five different occupations over this segment of his life cycle. The occupation on the last job was chosen. (See the note at the bottom of Table C.4)

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increase in earnings while the comparable effects at 10, 15 and 20 years of experience are 4.2%, 6.9% and 9.6% respectively. The training component, if that is the proper explanation, is, in fact, quite strong as earnings are estimated to be lower for the more educated for several years after initial employment. Notice that ability differences also have larger impacts at later experience.

Since the self-employed are not subject to an educationally based market screening process, there should be no relative certainty return to those who are more educated. Earnings profiles should, therefore, diverge to a greater extent for this group if the null hypothesis that systematic variation in post-schooling investment behavior with educational attainment is identical for both worker classes is maintained. There is no a priori judgment inherent within the human capital framework as to this comparison.

Looking at equation (1) in Table 1, the schooling-experience interaction term is seen to be larger for the self-employed as was suggested by the screening model. A one-tail t-test leads to a rejection of the null hypotheses of coefficient equality between the two samples.[17] However, that this may simply be a training effect cannot be ruled out. Qualitatively similar results are obtained for the managerial class (see Table C.4, equation 1).

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17 The t-value was 1.8.

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Consider also the ability-experience interaction. The ability effect increases with experience for private wage workers but is insignificant in the self-employed regression equation.[18] The implication of the screening model is that ability differences (if the ability measure reflects productivity endowments) will be discerned by employers and earnings will, thus, over time, more nearly reflect these differences. For the self-employed, no such effect should be observeable. However, it may be that the skills measured by the ability variable are less relevant for the self-employed. Indeed, a larger ability effect would be expected for this group at initial experience (P = 0) than for those privately employed since, if the latter are subject to screening, individuals of diverse abilities, even within the same schooling class, would initially be more equally compensated. This is apparently not the case; the ability measure appears not to capture job-relevant skills for the self-employed.

Basically, the same arguments can be made with respect to the impact of schooling quality on life-cycle earnings. If college quality, for example is used by firms as an informational device and there is a variance component to this return, profiles of different quality groups should converge with experience. On the other hand, if no

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[18] For the self-employed F = 0.992 while for private wage workers F = 35.935. These are derived from within-group regressions which naturally have identical coefficients as those given in the text but have different variance-covariance matrices of the coefficients.

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information is attached to knowing the college an individual attended, profiles should be identical. Note that if this knowledge is valueless to the firm, it is presumed that no skill differences exist. Assuming quality to be a valid screen, one should find no convergence in a comparison of private wage workers with the self-employed or, if training investments are for some reason positively correlated with college quality (ability constant), greater divergence. To facilitate the comparison, the subsample of college graduates (those with exactly 16 years of schooling) was chosen. Other sample restrictions are maintained. The regression equation is specified identically to that of equation (1) except that a college quality measure, Q, replace the schooling variable S and QP replaces SP. Results are presented in Table 2 combining all occupational categories. Managerial regressions are reported in Appendix C, Table C.8.

Consistent with the screening proposition, earnings profiles diverge to a greater extent as between college quality levels for the self-employed. However, the t-value associated with the test for coefficient equality is 0.5061 which implies no "significant" difference in the rate of divergence. This result is unaltered when only the managerial occupation is considered. Hence, there is no confirmation of a variance return to college quality.

The preceding formulations have attempted to discern the existence of a variance or relative certainty return to schooling which does not reflect productivity differences causally related to educational attainment. Admittedly, the tests are crude, yet the results generally do not confirm any substantial bias in schooling's return due to this factor. Clearly, further quantification of systematic post-school behavior as

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related to schooling, ability and college quality is essential.

The strategy has been to explore the implications of the two competing views of the schooling-income relationship and develop procedures which might indicate at least the direction, if not the magnitude, of schooling's predominant role. As noted, taken singly, the tests are not powerful; yet, cumulatively, the message is clear. A significant screening component is simply not revealed.

Because of the difficulties in designing and implementing procedures to isolate the two effects, it would be a useful exercise to outline an empirical specification which, ignoring data requirements, has strongly divergent implications under the two regimes. Such a model is outlined below. It is not intended as a complete specification of an appropriate test.

Consider a world composed of n geographic units (regions, countries) between which labor is completely immobile. Regions are assumed to be composed of individuals whose aggregate "ability" or endowed productivity distributions are identical. Suppose, moreover, that schooling serves only a screening function, and, because of taste differences or Spence's multiple equilibria, for example, schooling distributions (in particular, average schooling levels) diverge between regions. Also, for simplicity, assume that schooling's screening efficiency is the same in all regions in the sense that an additional year of schooling moves an individual up the ability distribution (in an identification sense) by exactly the same amount in all regions. For example, the average ability of those with 10 years of schooling in one region might correspond to the average ability of those with 12 years of schooling in another region and likewise for the schooling pairs (11, 13), (9, 11) etc.

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Under these assumptions, the rates of return to schooling obtained from simple within region schooling-earnings regressions would be identical for all regions. Consider, however, pooling the n samples and performing the following regression:

$$(2) \quad \ln Y_{ij} = \beta_o + \beta_1 S_{ij} + \beta_2 \bar{S}_j + \beta_3 X_{ij} + u_{ij}, \text{ where}$$

Y_{ij}, S_{ij} and X_{ij} are, respectively, the earnings, schooling level and other relevant characteristics of the i^{th} individual residing in the j^{th} region; $\bar{S}_j$ is the average schooling attainment of those individuals in the j^{th} region; and u is a disturbance term.

Clearly, an increase in an individual's schooling level (S_{ij}) will, holding the mean schooling level ($\bar{S}_j$) constant, increase earnings due to his improvement in position relative to other individuals. In fact $\hat{\beta}_1$ would be identical to the within-region schooling regression coefficients. However, an increase in $\bar{S}_j$, holding the i^{th} individual's own schooling level constant, would worsen his relative position, i.e., identify him with lower ability types and, thus, reduce his earnings. In a screening world, $\hat{\beta}_2$ would, therefore, be negative.

If these were the only implications, this framework would not be very useful. For, under a productivity augmenting view, the same predictions are possible although $\hat{\beta}_2$ could reasonably be positive if demand conditions were the cause of the different schooling investment patterns. There is, however, a much stronger prediction. If all individuals' schooling levels were augmented (or reduced) by an equal amount, say one year, any individual's earnings would be unchanged. Each individual would remain in exactly the same position relative to others as before.

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Thus, the sum of the two coefficients $(\hat{\beta}_1 + \hat{\beta}_2)$ should be zero. The more positive their sum, the less importance could one ascribe to the screening hypotheses.

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CHAPTER V

SUMMARY AND CONCLUSIONS

The dissertation was basically divided into two parts. The first portion (Chapter II) described a model of a competitive firm's employment decisions when some inputs are of uncertain quality. In particular, individual productivities were assumed to be unknown to the firm prior to hiring and neither instantaneously nor costlessly determinable from direct observation of on-the-job performance. Instead, the information available to the firm was restricted to knowledge (a subjective component was also treated) of the first two moments of the population's skill distribution. Output was assumed to be a function of occupation-specific aggregate skill levels and capital. Within an expected profit maximization framework, uncertainty or risk in the form of skill variance was shown to lead to a reduction in expected profits at the previous input scales. However, its effect on labor demand was seen to be ambiguous; when decomposed into substitution and output responses, the former may imply a greater utilization of the risky labor input. Although depending upon production function properties (in particular, third partial derivatives), the intuition for this result was simply that the firm substitutes toward those factors which most reduce the negative impact of skill variance on expected output.

The rationale for the use of screening devices, e.g., schooling, sex, age, etc., which may segment the population into classes differing in their skill distribution parameters, was next considered. It was demonstrated that the demand for individuals associated with a given (schooling) group depended upon both the average skill level and the variance-mean skill ratio of the group. Since skill variance reduces

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expected profits, the latter component was interpreted as a relative risk effect. With an imperfect device (one which does not perfectly predict productivities) production isoquants relating quantities of labor of different classes were, under plausible assumptions, shown to be convex. Given market wage adjustments as a result of screening, workers from different (schooling) classes may be employed within the same occupation. Moreover, since any device's sorting capability may differ across occupations, worker characteristics may also differ.

Applying the model specifically to education, it was seen that the relationship between income and schooling need not be due to skill augmentation. Schooling's private return can be viewed as a reflection of its informational content, i.e., its sorting function. Several models (Chapter III) which explicitly consider the individual's schooling decision in a screening world were considered. However, these formulations tended to ignore the social value of schooling's identification role. This point was then explored in the context of the previous model. In essence, eliminating between group skill variance through the use of screens was shown to lead to a more efficient allocation of workers both within and between firms. Therefore, even if the higher average skill levels associated with the more schooled were not produced in the schooling process, schooling's social benefit would not be zero. There are aggregate output gains from screening which may coexist with any mixture of the two views.

The second portion of the dissertation described some empirical attempts to disentangle the productivity and identification effects of schooling. The results of two previous studies were reported (Chapter III). The first attempted to discern the existence of the

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productivity effect while the second concentrated on the screening effect. The evidence for the existence of schooling's productivity enhancing role was seen to be greatly more convincing although the nature of the hypothesis did not rule out an important screening role as well.

Further empirical tests were performed and their results discussed in Chapter IV. Tests for both the mean and variance components of the return to schooling were conducted. Variance effects were, however, not readily distinguishable from on-the-job training effects. Nevertheless, it would be safe to conclude that no substantial upward bias in schooling's return was discernable as a result of the postulated relative risk premium.

Probably the strongest test for the existence of an identification effect was based upon a comparison between schooling's return to self-employed and private wage workers. Since the former are not subject to a screening process, i.e., there is no need for them to identify their capabilities through formal schooling, the absence of a productivity effect should manifest itself in a lower return to schooling than for the latter group. Using the NBER-Thorndike sample (see Chapter IV) in a longitudinal fashion, earnings regressions were estimated and profiles of the two worker classes compared. The schooling effect, either averaged over all life-cycle points or at alternative levels of experience, was shown not to be "significantly" different for the two groups. This result was maintained even after excluding the professional occupations and, thus, considering only those in the managerial category. Similar results were obtained for a comparison of the effect of higher "quality" undergraduate training on earnings between the two classes. It was demonstrated that the earnings of the self-employed are equally

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augmented by greater quality schooling, a result which would have to be due to skill augmentation rather than identification.

Further independent evidence related to this controversy was also discussed. For example, Welch's (20) income-schooling comparisons of rural farm workers (generally, they are self-employed) to urban workers supported the previous finding that the income gains from schooling are substantial even for groups not influenced by a screening motive. Further doubts as to the importance of the screening view were raised in a brief discussion of the growth accounting literature. It was also noted that the screening models surveyed in Chapter III did not appear capable of explaining the rapidly rising schooling levels observed over time.

An important point noted in Chapter IV and also stressed by other authors (Becker (3), Chiswick (5)) was that in order for schooling to serve mainly a screening function, one would have to discount the possibility that there would be market forces which, through the development of cheaper information sources, would destroy the screening motive for schooling investments. There are two reasons why market mechanisms might not be strong enough to bring about this result. Either the return from developing alternative sources of information are not large enough or schooling is predominantly a productivity augmenting instrument. The latter appeared more plausible given the existence of devices already in use (by schools) to predict school success and the substantiatial private cost of attending school.

In conclusion, the apparent use of schooling as a screening device did not appear from the empirical work presented in this dissertation, to stem from a mere identification of productivity types. The evidence,

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in fact, was such that a pure productivity augmenting view of the income-schooling relationship appeared greatly more tenable.

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APPENDIX A

This appendix to Chapter II first demonstrates the propositions in the text for the single skill input model and then generalizes the proofs to the multi-factor case including all of the distribution parameters discussed in the text.

1. The Single Skill Input Model.

Beginning with equations (13), (14), and (15), the proofs of which are given in the text, the pure substitution effect can be proved as follows:

$$(A.1)\quad \frac{1}{L}\frac{dL}{d\sigma^2} = -\phi_{L\sigma^2}\frac{\Delta_{LL}}{L\Delta} - \phi_{K\sigma^2}\frac{\Delta_{KL}}{L\Delta} .$$

Substituting for Δ_{LL} and Δ_{KL},

$$(A.2)\quad \frac{1}{L}\frac{dL}{d\sigma^2} = \frac{(-\phi_{L\sigma^2})(-\phi_{rL})}{L\Delta} - \frac{(\phi_{K\sigma^2})(\phi_{rL}\phi_{w})}{L\Delta}$$

$$= \left(\frac{\phi_{L\sigma^2}}{\phi_L} - \frac{\phi_{K\sigma^2}}{\phi_K}\right)\left(\frac{\phi_L\phi_K^2}{L\Delta}\right)\left(\frac{K\phi_K}{L\phi_L+K\phi_K}\right)\Big/\frac{K\phi_K}{L\phi_L+K\phi_K}$$

$$= \left(\frac{\phi_{L\sigma^2}}{\phi_L} - \frac{\phi_{K\sigma^2}}{\phi_K}\right)\frac{\phi_L\phi_K}{LK\Delta}(L\phi_L+K\phi_K)\,\alpha_K$$

$$= \sigma_{LK}\alpha_K\left(\frac{\phi_{L\sigma^2}}{\phi_L} - \frac{\phi_{K\sigma^2}}{\phi_K}\right) .$$

Similarly,

$$(A.3)\quad \frac{1}{K}\frac{dK}{d\sigma^2} = -\phi_{L\sigma^2}\frac{\Delta_{LK}}{K\Delta} - \phi_{K\sigma^2}\frac{\Delta_{KK}}{K\Delta}$$

which, upon substituting for Δ_{LK} and Δ_{KK}, and performing the same manipulations as above, reduces to

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$$(A.4)\quad \frac{1}{L}\frac{dK}{d\sigma^2} = -\sigma_{LK}\alpha_L\left(\frac{\phi_{L\sigma^2}}{\phi_L} - \frac{\phi_{K\sigma^2}}{\phi_K}\right).$$

Subtracting A.4 from A.3, realizing that $\alpha_L + \alpha_K = 1$, yields A.5, the percentage alteration in factor ratios due to a change in variance.

$$(A.5)\quad \frac{1}{L}\frac{dL}{d\sigma^2} - \frac{1}{K}\frac{dK}{d\sigma^2} = \sigma_{LK}\left(\frac{\phi_{L\sigma^2}}{\phi_L} - \frac{\phi_{K\sigma^2}}{\phi_K}\right).$$

Substituting

$$\phi_L = \mu\,(F_{\bar{S}} + \tfrac{1}{2}RF_{\bar{S}\bar{S}} + \tfrac{1}{2}R\bar{S}\,F_{\bar{S}\bar{S}\bar{S}}),$$

$$\phi_K = F_K + \tfrac{1}{2}\,R\bar{S}F_{\bar{S}\bar{S}K},$$

$$\phi_{L\sigma^2} = \tfrac{1}{2}\,\bar{S}F_{\bar{S}\bar{S}\bar{S}} + \tfrac{1}{2}\,F_{\bar{S}\bar{S}},$$

and $$\phi_{K\sigma^2} = \frac{1}{2\mu}\,\bar{S}\,F_{\bar{S}\bar{S}K}$$

into A.5, it is seen that the pure substitution effect does depend on third partial derivatives.

$$(A.6)\quad \frac{1}{L}\frac{dL}{d\sigma^2} - \frac{1}{K}\frac{dK}{d\sigma^2} \sim \bar{S}F_K F_{\bar{S}\bar{S}\bar{S}} - \bar{S}F_{\bar{S}}F_{\bar{S}\bar{S}K} + F_K F_{\bar{S}\bar{S}}.$$

That marginal expected cost must increase with the introduction of uncertainty can be demonstrated as follows. Setting $\frac{d\bar{Y}}{d\sigma^2} = 0$, i.e., restoring output to its original level, and assuming no substitution effect ($\frac{\phi_{L\sigma^2}}{\phi_L} - \frac{\phi_{K\sigma^2}}{\phi_K} = 0$), from (13) in the text, A.7 is obtained.

$$(A.7)\quad \frac{d\lambda/\lambda}{d\sigma^2} = [-\phi_{\sigma^2}\Delta_0 - \gamma(\phi_L\Delta_L + \phi_K\Delta_K)]/\Delta$$

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where $\gamma = \frac{\phi_{L\sigma^2}}{\phi_L} = \frac{\phi_{K\sigma^2}}{\phi_K}$. Substituting for Δ_L and Δ_K,

$$(A.8) \quad \frac{d\lambda/\lambda}{d\sigma^2} = -\frac{\phi_{\sigma^2}\Delta_o - \gamma T}{\Delta}$$

where $T = \phi_L^2\phi_{KK} - \phi_K^2\phi_{LL} + 2\phi_L\phi_K\phi_{KL}$. But

$T > 0$ is the condition for cost minimization,

$\Delta_o > 0$ is the condition for profit maximization and

$\phi_{\sigma^2} < 0$ as previously demonstrated. Thus, marginal expected cost must rise as long as variance reduces marginal expected products, i.e., $\gamma < 0$.

The net scale effect is found by setting $\frac{d\bar{Y}}{d\sigma^2} - \phi_{\sigma^2} = 0$. From (13),

$$(A.9) \quad \frac{d\lambda/\lambda}{d\sigma^2} = (-\phi_{L\sigma^2}\Delta_L - \phi_{K\sigma^2}\Delta_K)/\Delta$$

$$= -\left(\frac{\phi_{L\sigma^2}}{\phi_L}\frac{\phi_L\Delta_L}{\Delta} + \frac{\phi_{K\sigma^2}}{\phi_K}\frac{\phi_K\Delta_K}{\Delta}\right).$$

But $\frac{\Delta_L}{\Delta} = \frac{\partial\lambda}{\partial P_L}$. Thus $\frac{d\lambda/\lambda}{dP_L/P_L} = \frac{P_L}{\lambda}\frac{\Delta_L}{\Delta} = \phi_L\frac{\Delta_L}{\Delta}$.

Similarly, $\frac{d\lambda/\lambda}{dP_K/P_K} = \phi_K\frac{\Delta_K}{\Delta}$. Therefore,

$$(A.10) \quad \frac{d\lambda/\lambda}{d\sigma^2} = -\left(\frac{\phi_{L\sigma^2}}{\phi_L}\frac{P_L}{EP_L} + \frac{\phi_{K\sigma^2}}{\phi_K}\frac{P_K}{E_K}\right).$$

With the introduction of schooling as a screening device, expected output is given by equation (22) in the text as demonstrated. The marginal rate of substitution for workers from the two schooling classes is found in the usual manner. Totally differentiating (22) and setting $d\bar{Y} = 0$ yields

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(A.11) $d\bar{Y} = \mu_C \phi_{\bar{S}} dL_C + \mu_H \phi_{\bar{S}} dL_H + \phi_R \frac{\partial R}{\partial L_C} dL_C + \phi_R \frac{\partial R}{\partial L_H} dL_H = 0.$

Substituting $\frac{\partial R}{\partial L_C} = \frac{\mu_C}{\bar{S}} (R_C - R)$ and $\frac{\partial R}{\partial L_H} = \frac{\mu_H}{\bar{S}} (R_H - R)$,

where $R_C = \frac{\sigma_C^2}{\mu_C}$ and $R_H = \frac{\sigma_H^2}{\mu_H}$, into A.11, A.12 is obtained.

(A.12) $d\bar{Y} = 0 = dL_C \left[\mu_C \phi_{\bar{S}} - R\phi_R \frac{\mu_C}{\bar{S}} + R_C \phi_R \frac{\mu_C}{\bar{S}}\right]$

$+ dL_H \left[\mu_H \phi_{\bar{S}} - R\phi_R \frac{\mu_H}{\bar{S}} + R_H \phi_R \frac{\mu_H}{\bar{S}}\right]$

or

(A.13) $\frac{-dL_C}{dL_H} = \frac{\mu_H}{\mu_C} \left(\frac{\bar{S}\phi_{\bar{S}} - R\phi_R + R_H \phi_R}{S\phi_S - R\phi_R + R_C R_R} \right)$

To demonstrate the convexity condition for the production isoquants, differentiate A.13 with respect to L_H. Defining $k_C = \bar{S}\phi_{\bar{S}} - R\phi_R + R_C\phi_R$ and $k_H = \bar{S}\phi_{\bar{S}} - R\phi_R + R_H\phi_R$, one obtains

(A.14) $- \frac{\mu_C k_C^2}{\mu_H} \cdot \frac{d^2 L_C}{dL_H^2}$

$= k_C \left[\bar{S}\phi_{\bar{S}\bar{S}} \frac{d\bar{S}}{dL_H} + \bar{S}\phi_{\bar{S}R} \frac{dR}{dL_H} + \phi_{\bar{S}} \frac{d\bar{S}}{dL_H} \right.$

$\left. - R\phi_{R\bar{S}} \frac{d\bar{S}}{dL_H} - \phi_R \frac{dR}{dL_H} + R_H \phi_{R\bar{S}} \frac{d\bar{S}}{dL_H} \right]$

$- k_H \left[\bar{S}\phi_{\bar{S}\bar{S}} \frac{d\bar{S}}{dL_H} + \bar{S}\phi_{\bar{S}R} \frac{dR}{dL_H} + \phi_{\bar{S}} \frac{d\bar{S}}{dL_H} \right.$

$\left. - R\phi_{R\bar{S}} \frac{d\bar{S}}{dL_H} + R_C \phi_{R\bar{S}} \frac{d\bar{S}}{dL_H} \right]$

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$$= (k_C-k_H)\left[\bar{S}\phi_{SS}^{--}\frac{d\bar{S}}{dL_H} + \bar{S}\phi_{SR}^{--}\frac{dR}{dL_H} + \phi_S^{-}\frac{d\bar{S}}{dL_H}\right.$$

$$\left. -R\phi_{RS}^{-}\frac{d\bar{S}}{dL_H} - \phi_R\frac{dR}{dL_H}\right] + \phi_{RS}^{-}\frac{d\bar{S}}{dL_H}(k_CR_H-k_HR_C).$$

But, $k_CR_H - k_HR_C = (R_H-R_C)(\bar{S}\phi_S^{-} - R\phi_R)$, and

$k_C-k_H = -\phi_R(R_H-R_C)$ so that

$$k_CR_H - k_HR_C = -(k_C-k_H)\left(\frac{\bar{S}\phi_S^{-}}{\phi_R} - R\right).$$

Also, $\frac{d\bar{S}}{dL_H} = \mu_H + \mu_C\frac{dL_C}{dL_H} = \frac{\mu_H}{k_C}(k_C-k_H)$ and

$$\frac{dR}{dL_H} = \frac{\partial R}{\partial L_H} + \frac{\partial R}{\partial L_C}\frac{dL_C}{dL_H} = \frac{-\mu_H(k_C-k_H)}{k_C}\left(\frac{\phi_S^{-}}{\phi_R}\right)$$

Substitution of these expressions into A.14 and rearranging term yields

$$(A.15)\quad -\frac{d^2L_C}{dL_H^2} = \frac{\mu_H^2(k_C-k_H)^2}{\mu_Ck_C}\left[\frac{\bar{S}\phi_{SS}^{--} + 2\phi_S^{-} - 2\bar{S}\phi_{SR}^{-}\phi_S^{-}}{\phi_R}\right]$$

which will be negative if and only if

$$(A.16)\quad \bar{S}\phi_{SS}^{--} < 2\frac{\phi_S^{-}}{\phi_R}(\bar{S}\phi_{SR}^{-}-\phi_R),$$

or $(A.17)\quad \phi_{SS}^{--} < \bar{S}\phi_S^{-}F_{SSS}^{---}$ since $\bar{S}\phi_{SR}^{-}-\phi_R = \frac{1}{2}\bar{S}^2F_{SSS}^{---}$.

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2. The Multi-factor Model.

Attention is now restricted to the formulation of expected output given by equation (29) in the text. To obtain that result, it is assumed that firms believe the mean skill level to be the true mean with some subjective variation attached to their belief. Assuming that firms with greater uncertainty can expect to sample no worse than firms with more confidence in their beliefs, and that this type of subjective uncertainty is uncorrelated over occupations, the approximation of expected output is simply additive in the two two types of variance. Specifically, $\bar{s}_j$ is distributed with mean μ_j and variance σ_j^2/L_j while μ_j is subjectively distributed with mean μ_j and variance $\hat{\sigma}_j^2$. Thus, their difference, $\bar{s}_j - \mu_j$, is distributed with mean zero and variance $\sigma_j^2/L_j + \hat{\sigma}_j^2$ under the covariance assumptions previously made. Expected output is, therefore,

$$(A.18)\quad \bar{Y} = F(\bar{S}_1, \bar{S}_2, \ldots, \bar{S}_v, K) + \tfrac{1}{2} \Sigma R_j \bar{S}_j F_{\bar{S}_j \bar{S}_j} + \tfrac{1}{2} \Sigma \hat{R}_j \bar{S}_j^2 F_{\bar{S}_j \bar{S}_j}$$

where $R_j = \sigma_j^2/\mu_j$ and $\hat{R}_j = \hat{\sigma}_j^2/\mu_j^2$. The equilibrium conditions for the competitive firm are:

$$(A.19)\quad \bar{Y} = \phi(\bar{S}_1, \bar{S}_2, \ldots, \bar{S}_v, R_1, R_2, \ldots, R_v, \hat{R}_1, \hat{R}_2, \ldots, \hat{R}_v, K)$$

$$(A.20)\quad P_{L_j} = \lambda \phi_{L_j}, \quad j = 1, \ldots, v$$

$$(A.21)\quad P_K = \lambda \phi_K$$

$$(A.22)\quad \lambda = MC = P_Y.$$

Totally differentiating with respect to σ_ℓ^2 (or $\hat{\sigma}_\ell^2$) and rewriting in matrix notation yields

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$$(A.23)\quad \begin{pmatrix} 0 & \phi_{L_1} & \cdots & \phi_{L_V} & \phi_K \\ \phi_{L_1} & \phi_{L_1L_1} & \cdots & \phi_{L_1L_V} & \phi_{L_1K} \\ \vdots & \vdots & & \vdots & \vdots \\ \phi_{L_V} & \phi_{L_VL_1} & \cdots & \phi_{L_VL_V} & \phi_{L_VK} \\ \phi_K & \phi_{KL_1} & & \phi_{KL_V} & \phi_{KK} \end{pmatrix} \begin{pmatrix} \frac{d\lambda/\lambda}{d\sigma_\ell^2} \\ dL_1/d\sigma_\ell^2 \\ \vdots \\ dL_V/d\sigma_\ell^2 \\ dK/d\sigma_\ell^2 \end{pmatrix} = \begin{pmatrix} \frac{d\bar{Y}}{d\sigma_\ell^2} - \phi_{\sigma_\ell^2} \\ -\phi_{L_1}\sigma_\ell^2 \\ \vdots \\ -\phi_{L_V}\sigma_\ell^2 \\ -\phi_K\sigma_\ell^2 \end{pmatrix}$$

Solving for $\frac{dL_k}{d\sigma_\ell^2}$, the effect of skill variance in the ℓ^{th} labor input on the employment of the k^{th}, yields

$$(A.24)\quad \frac{dL_k}{d\sigma_\ell^2} = \left(\frac{d\bar{Y}}{d\sigma_\ell^2} - \phi_{\sigma_\ell^2} \right) \Delta L_k - \sum_{j=1}^{V} \phi_{L_j}\sigma_\ell^2 \Delta L_jL_k - \phi_K\sigma_\ell^2 \Delta KL_k \Big/ \Delta,$$

where Δ is the determinant of the left hand square matrix and the subscripted Δ's are the relevant cofactors. The pure substitution effect is (recall that $\frac{d\bar{Y}}{\sigma_\ell^2} - \phi_{\sigma_\ell^2}$ is set equal to zero)

$$(A.25)\quad \frac{1}{L_k}\frac{dL_k}{d\sigma_\ell^2} = - \sum_{j=1}^{V} \frac{\phi_{L_j}\sigma_\ell^2}{\phi_{L_j}} \cdot \frac{\phi_{L_j}\Delta_{L_jL_K}}{L_k\Delta} + \frac{\phi_K\sigma_\ell^2}{\phi_K} \cdot \frac{\phi_K \Delta_{KL_k}}{L_k\Delta} .$$

But, from Allen (1), $\alpha_j\sigma_{jk} = \frac{\phi_{L_j}\Delta_{L_jL_k}}{L_k\Delta}$ where

σ_{jk} is the Allen-Uzawa partial elasticity of substitution. Therefore,

$$(A.26)\quad \frac{1}{L_k}\frac{dL_k}{d\sigma_\ell^2} = - \sum \alpha_j\sigma_{jk} \frac{\phi_{L_j}\sigma_\ell^2}{\phi_{L_j}} + \alpha_K\sigma_{Kk} \frac{\phi_K\sigma_\ell^2}{\phi_K} .$$

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Notice that for the c[illegible]skill input model, $\alpha_L\sigma_{LL} = -\alpha_K\sigma_{KL}$ so that equation A.2 reduces from A.26. The net scale effect is demonstrated in a similar manner and is given by

$$(A.27)\quad \frac{d\lambda/\lambda}{d\sigma_\ell^2} = -\sum_j \frac{\phi_{L_j}\sigma_\ell^2}{\phi_{L_j}}\frac{E_\lambda}{EP_{L_j}} - \frac{\phi_K\sigma_\ell^2}{\phi_K}\frac{E_\lambda}{EP_K}.$$

The reason that results may not be symmetric for $\hat{\sigma}_\ell^2$ is simply because $\phi_{L_j}\sigma_\ell^2 \neq \phi_{L_j}\hat{\sigma}_\ell^2$. Notice that

$$(A.28)\quad \phi_{L_j}\sigma_\ell^2 = \tfrac{1}{2}\mu_j L_\ell F_{\bar{S}_\ell\bar{S}_\ell\bar{S}_j} \quad \text{for } j\neq\ell \text{ and}$$

$$\phi_{L_\ell}\sigma_\ell^2 = \tfrac{1}{2}(\bar{S}_\ell F_{\bar{S}_\ell\bar{S}_\ell\bar{S}_\ell} + F_{\bar{S}_\ell\bar{S}_\ell})$$

and

$$(A.29)\quad \phi_{L_j}\hat{\sigma}_\ell^2 = \tfrac{1}{2}\mu_j L_\ell^2 F_{\bar{S}_\ell\bar{S}_\ell\bar{S}_j} \quad \text{for } j\neq\ell \text{ and}$$

$$\phi_{L_\ell}\hat{\sigma}_\ell^2 = \tfrac{1}{2}(L_\ell\bar{S}_\ell F_{\bar{S}_\ell\bar{S}_\ell\bar{S}_\ell} + F_{\bar{S}_\ell\bar{S}_\ell}).$$

Thus,

$$(A.30)\quad \phi_{L_j}\hat{\sigma}_\ell^2 = \phi_{L_j}\sigma_\ell^2 \cdot L_\ell \quad \text{and}$$

$$\phi_{L_\ell}\hat{\sigma}_\ell^2 = L_\ell(\phi_{L_\ell}\sigma_\ell^2 + \tfrac{1}{2}F_{\bar{S}_\ell\bar{S}_\ell}).$$

For a linear homogeneous production function, twice differentiating Euler's equation with respect to $\bar{S}_\ell$ yields

$$(A.31)\quad \bar{S}_1 F_{\bar{S}_1\bar{S}_\ell\bar{S}_\ell} + \bar{S}_2 F_{\bar{S}_2\bar{S}_\ell\bar{S}_\ell} + \ldots + \bar{S}_\ell F_{\bar{S}_\ell\bar{S}_\ell\bar{S}_\ell} + \Gamma_{\bar{S}_\ell\bar{S}_\ell} + \ldots$$

$$+ \bar{S}_v F_{\bar{S}_v\bar{S}_\ell\bar{S}_\ell} + K F_{K\bar{S}_\ell\bar{S}_\ell} = 0$$

or, using (A.28),

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$$(A.32)\quad \Sigma\, \alpha_j \frac{\phi_{L_j}\sigma_\ell^2}{\phi_{L_j}} = 0.$$

Since for a linear homogeneous function $\frac{E\lambda}{EP_{L_j}} = \alpha_j$,

(A.32) is identical to the net scale effect given in (A.27). Thus, for this function, the initial reduction in output due to an increase in skill variance for any single occupation is also the full reduction.

However, for $\hat{\sigma}_j^2$, the Euler equation implies

$$(A.33)\quad \Sigma\alpha_j \frac{\phi_{L_j}\hat{\sigma}_\ell^2}{\phi_{L_j}} = \tfrac{1}{2} L_\ell^2 F_{\bar{S}_\ell \bar{S}_\ell} < 0$$

so that the net scale effect due to the introduction of $\hat{\sigma}_\ell^2$ must be positive; equilibrium output will be lower than the partial reduction given by $\phi\hat{\sigma}_\ell^2$.

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APPENDIX B

This appendix demonstrates the propositions concerning schooling's social return as an identification device that was outlined in Chapter III.

Aggregate output is given by

$$(B.1) \quad \sum_{j=1}^{N} Y_i = NF + \tfrac{1}{2} L^2 F_{SS} \sum_{j=1}^{N} (\bar{s}_i - \mu)^2$$

as demonstrated in the text. With schooling serving as a perfect screen,

$$\bar{s}_i = \mu_H \frac{L_{Hi}}{L} + \mu_C \frac{L_{Ci}}{L}$$

since each firm must obtain μ_H and μ_C units of skill from each individual within the two respective schooling classes. Since

$$\mu = \mu_H \frac{L_H}{NL} + \mu_C \frac{L_C}{NL}$$

where $\sum_i L_{Hi} = L_H$, $\sum_i L_{Ci} = L_C$, $L_H + L_C = NL$, $L = L_{Hi} + L_{Ci}$, N being the number of firms and L each firm's labor input,

$$(B.2) \quad L^2 \sum_i (\bar{s}_i - \mu)^2 = \sum_i \left[\mu_H \left(L_{Hi} - \frac{L_H}{N}\right) + \mu_C \left(L_{Ci} - \frac{L_C}{N}\right)\right]^2 .$$

But $\left(L_{Hi} - \frac{L_H}{N}\right) = -\left(L_{Ci} - \frac{L_C}{N}\right)$ since $L_{Hi} + L_{Ci} = L = \frac{L_H}{N} + \frac{L_C}{N}$.

Thus,

$$(B.3) \quad L^2 \Sigma (\bar{s}_i - \mu)^2 = (\mu_C - \mu_H)^2 \Sigma \left(L_{Ci} - \frac{L_C}{N}\right)^2$$ which is equation (12) in the text.

With imperfect screening, each firm's sample mean skill level from sampling within schooling classes will not be identical to the actual means since σ_H^2, $\sigma_C^2 \neq 0$.

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Therefore, $\bar{s}_i = \bar{s}_{Ci} \frac{L_{Ci}}{L} + \bar{s}_{Hi} \frac{L_{Hi}}{L}$ and

$$(B.4) \quad L^2 \sum_i (\bar{s}_i - \mu)^2 = \sum_i \{ [\bar{s}_{Ci} L_{Ci} - \mu_C \frac{L_C}{N}] + [\bar{s}_{Hi} L_{Hi} - \mu_H \frac{L_H}{N}] \}^2 .$$

Moreover,

$$\bar{s}_{Ci} = s_A \frac{L_{ACi}}{L_{Ci}} + s_B \frac{L_{BCi}}{L_{Ci}}, \quad \mu_C = s_A \frac{L_{AC}}{L_C} + s_B \frac{L_{BC}}{L_C}$$

$$\bar{s}_{Hi} = s_A \frac{L_{AHi}}{L_{Hi}} + s_B \frac{L_{BHi}}{L_{Hi}}, \quad \mu_H = s_A \frac{L_{AH}}{L_H} + s_B \frac{L_{BH}}{L_H}$$

with L_{AC} being the number of A individuals in education class E_C and similar definitions for L_{AH}, L_{BC}, L_{BH}.

Hence,

$$(B.5) \quad L^2 \sum_i (\bar{s}_i - \mu)^2 = \sum_i [s_A (L_{ACi} + L_{AHi} - \frac{L_{AC}}{N} - \frac{L_{AH}}{N}) + s_B (L_{BCi} + L_{BHi} - \frac{L_{BC}}{N} - \frac{L_{BH}}{N})]^2.$$

But, $L_{ACi} + L_{AHi} - \frac{L_{AC}}{N} - \frac{L_{AH}}{N} = - (L_{BCi} + L_{BHi} - \frac{L_{BC}}{N} - \frac{L_{BH}}{N})$.

Finally,

$$(B.6) \quad L^2 \sum_i (\bar{s}_i - \mu)^2 = (s_A - s_B)^2 \sum_i \{ [L_{ACi} - \frac{L_{AC}}{N}] + [L_{AHL} - \frac{L_{AH}}{N}] \}^2.$$

Since, under screening, those firms which sample well from both schooling classes, i.e., large proportions of A workers, must exactly be offset by firms sampling poorly as the number of workers sampled from each schooling class is the same for every firm, the effect of between schooling class skill variance has been eliminated. Variation within classes still remains, and, thus, schooling's social value is smaller than under perfect screening.

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For the multi-skill input model discussed in the text, it is only necessary to add that, by allocating workers to occupations through the use of schooling as an informational device, the mean skill level of the population from which it samples is boosted. In the example given in the text, the net effect of screening is to raise μ_1 (thus $\bar{S}_1$), and make the latter two terms in equation (14) zero.

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APPENDIX C

TABLE C.1

Means and Standard Deviations of Selected Variables

for Private Wage and Salary Workers

	All Occupations		Excluding Teachers and Professionals	
	Means	Standard Deviations	Means	Standard Deviations
Ln Earnings	8.921	0.5696	9,944	0.5789
Schooling	15.61	2.181	14.97	1.996
Experience	10.62	8.332	10.87	8.418
Age	35.80	9.328	35.74	9.420
Ability	0.1555	1.809	.0811	1.821
Earnings	8,832	5,897	9.107	6,314
# of Observations	7893		5595	

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TABLE C.2

Means and Standard Deviations of Selected Variables

for the Self-Employed:

All Occupations

	Means	Standard Deviations
Ln Earnings	9.116	o.7027
Schooling	15.31	2.345
Experience	10.60	8.692
Age	35.44	10.06
Ability	0.117	1.769
Earnings	11,860	10,420
# of Observations:	1.906	

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TABLE C-3

Means and Standard Deviations of Selected Variables

for the Managerial Occupations

	Private Wage		Self Employed	
	Means	Standard Deviation	Means	Standard Deviation
Ln Earnings	9.030	0.6015	9.119	06991
Schooling	15.50	1.870	14.63	1.789
Experience	10.76	8.235	10.89	8.800
Age	35.89	8.603	35.45	9.961
Ability	0.3815	1,820	0.0388	1.811
Earnings	10,060	6,993	11,890	10,590
# of Observations	3,512		1,238	

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TABLE C-4

Earnings Regressions for Self-Employed and Private Managers[a]

	(1)		(2)		(3)	
	Private	S.E.	Private	S.E.	Private	S.E.
S	-0.0150	-0.0355	0.0362	0.0184	0.0316	0.0189
	(2.30)	(3.20)	(9.18)	(2.65)	(7.78)	(2.65)
P	0.0131	-0.0064	0.0319	0.0683	0.0819	0.0683
	(1.61)	(0.30)	(26.84)	(13.55)	(26.84)	(13.55)
P^2	-0.0011	-0.0007	-0.0013	-0.0008	-0.0013	-0.0008
	(8.44)	(3.01)	(9.35)	(3.50)	(9.38)	(3.50)
SP	0.0042	0.0050	-			
	(8.93)	(6.31)				
A	-0.0048	-0.0155	-		0.0190	-0.0021
	(0.72)	(1.42)			(4.59)	(0.30)
AP	0.0022	0.0012	-			
	(4.45)	(1.57				
Intercept	-0.4252	9.0459	-0.4353	8.2557	-0.0631	8.2482
	(2.20)	(55.42)	(3.59)	(79.93)	(2.93)	(77.81)
R^2	.5457		.5265		.5286	

(a) With respect to occupation, a great deal of upward mobility occurred with many individuals moving into the managerial class. Few individuals remained in the same occupation throughout their work experience. However, the last job for categorization was chosen on the basis that any work experience prior to moving into this occupation would be most relevant for this occupation rather than previous experience.

An alternative would have been to utilize only the information on the last job. However, there would be little variation in experience as all individuals first entered into employment between 1945 and 1952. This method would ignore the longitudinal aspects of the sample which, in fact, make this data set desirable.

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TABLE C.5

Occupational Distributions for Private Wage and Self-Employed Workers (a)

Occupation	Private		Self-Employed	
None reported	181	(2.3%)	89	(4.7%
Educator	865	(11.0$)	8	(0.4%)
Professional	1252	(14.9%)	347	(18.2%)
Executive-Manager	3512	(44.5%)	1238	(65.0%)
Commissioned Salesman	604	(7.7%)	105	(5.5%)
Technical	532	(6.7%)	106	(5.6%)
Skilled-Manual	350	(4.4%)	5	(0.3%)
Semi-Skilled and Unskilled Manual	104	(1.3%)	0	(0.0%)
Service, Clerical Laborer	294	(3.7%)	0	(0.0%)
Other (b)	199	(2.5%)	8	(0.4%)
TOTAL	7893	(100.0%)	1906	(100.0%)

(a) Both major and minor occupational categories are reported. The table refers only to the former and, as previously noted, only to the last job.

(b) This includes Trainees, Apprentices, Journeymen and Miscellaneous White Collar Workers.

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TABLE C.6

Means and Standard Deviations fo Selected Variables for

Private Wage and Self-Employed College Graduates:

All Occupations

	Private		Self-Employed	
	Means	Standard Deviations	Means	Standard Deviations
Ln Earnings	8.9718	.5964	9.1090	.7259
Experience	10.228	8.018	10.180	8.4066
Age	35.697	8.739	35.494	9.249
Abiltiy	0.5128	1.779	0.4675	1.773
Quality	4.9522	1.0478	5.0171	0.9933
Earnings	9,347	6,163	11,947	
# of Observations	3012		688	

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TABLE C.7

Means and Standard Deviations of Selected Variables for

Private Wage and Self-Employed College Graduates Managers

	Private		Self-Employed	
	Means	Standard Deviations	Means	Standard Deviations
Ln Earnings	9.042	0.6075	9.112	0.7351
Experience	10.42	7.993	10.30	8.392
Age	35.76	8.282	35.37	9.507
Ability	0.5372	1.798	.4239	1.832
Quality	5.031	1.070	5.015	1.000
Earnings	10,180	6.769	12,080	10,970
# of Observations	1624		487	

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TABLE C.8

College Quality Regressions for College Graduates: Managers

Coefficients (t-values in parenthesis)

	Private	Self-Employed
P	0.0820 (11.3459)	0.0660 (4.8502)
P^2	-0.0015 (7.9462)	-.0013 (3.8507)
Q	0.0211 (1.3495)	0.0070 (0.2340)
QP[a]	0.0019 (1.5934)	0.0049 (2.1558)
A	0,0018 (0.1917)	0.0059 (0.3757)
AP	0.0020 (2.8150)	-0.0005 (0.4704)
Intercept	-0.1437 (0.8434)	8.3823 (55.7596)
R^2	.6153	

(a) These coefficients are not "statistically" different as t=1.18.

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TABLE C.9

Earnings Regressions for All Individuals with the Same Worker Class on 1st and 5th Job[a] [b]

(Coefficients (t-values)

	(1)		(2)		(3)	
	Private	S.E.	Private	S.E.	Private	S.E.
S	-0.0233	-0.0016	0.0262	0.0460	0.0203	0.0476
	(6.55)	(0.18)	(11.79)	(8.02)	(8.01)	(8.08)
P	0.0129	-0.0059	0.0803	0.0725	0.0800	0.0726
	(2.76)	(0.48)	(39.93)	(10.97)	(40.08)	(11.06)
P^2	-0.0013	-0.0010	-0.0018	-0.0012	-0.0015	-0.0012
	(14.94)	(3.35)	(16.73)	(4.25)	(16.74)	(4.29)
SP	0.0041	0.0048	-	-	-	-
	(15.58)	(7.36)				
A	0.0043	0.0001	-	-	0.0279	-0.0104
	(1.01)	(0.004	-		(10.34	(1.08
AP	0.0022	-0.009	-	-	-	-
	(6.85)	(0.89)				
Intercept	0.0134	8.6993	-0.037	7.9705	0.0757	7.9462
	(0.09)	(63.51)	(0.38)	(87.62)	(0.76)	(85.32)
R^2	.5335		.5029		.5094	

(a) There are 8260 observations, 7,570 private and 690 self-employed. Thus 1,187 observation previously classified as self-employed were private wage workers on their first job while only 270 were oppositely classified.

(b) SP not statistically different in equation (1). S statistically different in equation (3).

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